Determination of Acoustic Properties of Noise Barriers

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Introduction

The acoustic performance of noise barriers is determined by many parameters. In general minimum values for the absorption and insulation are prescribed. These minimum requirements are then tested on a sample of the barrier by laboratory measurements (EN1793-1 [1] and/or EN1793-2 [2]). In-situ testing of the requirements occurs rarely.

Recently major improvements in the measurement methods for determining the in-situ values of noise barriers have been implemented. Laboratory and in-situ measurements have been compared. The results are not directly comparable, due to differences between the diffuse, omnidirectional sound field in the laboratory and the limited incidence angles that occur in the field. Additionally, new measurement methods have been developed by the University of Twente and SoundInSight, which are suitable to determine the acoustic properties of noise barriers in-situ, for any complex sound field.

In this study, the relation between EN1793 laboratory and in-situ measurements is quantified, based on an extended measurement program of laboratory and in-situ techniques on different noise barrier samples. The SonoCat technique developed by SoundInSight has also been applied. The results for all three measurement methods are presented and discussed. The goal is to enable the validation and conformity of the lab-based acoustic requirements of noise barriers with in-situ measurement methods. Within this research program the focus was on the acoustic insulation of noise barriers.

Acoustic properties of noise barriers

The acoustic performance of noise barriers is mainly determined by the following properties:

- acoustic insulation: to minimize transmission of sound through the barrier;
- acoustic absorption: to minimize reflection of sound at the barrier;
- diffraction at the top.

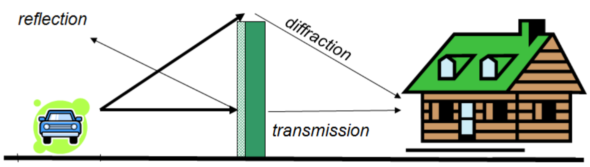

Figure 1: Transmission, reflection and diffraction by a noise barrier

Besides these intrinsic characteristics of a noise barrier, the transfer path and meteorological conditions also determine the insertion loss for the receiver. Within this research program we have focused on the intrinsic characteristics of noise barriers, and the acoustic insulation in special.

Quantification

At this moment the acoustic demandments of noise barriers are related to the determination of its acoustic properties (absorption and insulation) by laboratory measurements. These measurements determine these properties on a (well-defined) sample of the noise barrier. The measurements are performed in a reverberation room.

For the acoustic absorption and insulation these results are presented in categories and single number values. Although spectral results are available, noise barriers are hardly judged on its spectral performance. In the Netherland, research has been done on the possibility to introduce spectral demandments for the absorbing properties of noise barriers. There is a possibility that the Dutch Road Authority will introduce these demandments in its legislation.

However, national road and rail authorities more and more are looking for a quality check of noise barriers realized along roads and railways. What is the acoustic quality of the realized noise barriers in relation to what is measured in the laboratory?

Measurement Methods

To determine the acoustic properties of noise barriers, the following measurement methods are commonly used:

Laboratory Measurements

<u>Acoustic absorption according to EN 1793-1 [1]:</u>

This European Standard specifies a test method for qualifying the sound absorption performance of noise reducing devices designed for roads (a measure of intrinsic performance. The test is designed to allow the intrinsic sound absorption performance of the device to be measured; the resulting rating should aid the selection of devices for particular roadside applications. The test method is derived from EN ISO 354:2003[9] and based on the placement of the test sample in a reverberation room. The absorbing properties are then measured by comparing the reverberation times of the empty room and the room with the test sample.

Acoustic insulation according to EN 1793-2 [2].

This European Standard specifies the laboratory method for measuring the airborne sound insulation performance of road traffic noise reducing devices in reverberant conditions. It covers the assessment of the intrinsic performance of barriers that can reasonably be assembled inside the testing facility described in EN ISO 10140-2 [7] and EN ISO 10140-4 [8].

The measurement results of this method for airborne sound insulation are comparable but not identical with the results of the test method EN 1793-6 [5], mainly because the present method uses a diffuse sound field, while the other method assumes a directional sound field. However, research studies suggest that a quite good correlation exists between the two methods.

Figure 2: Reverberation room measurements (EN 1793-1)

In-Situ Measurements

Acoustic absorption (EN 1793-5 [4]) and acoustic insulation (EN 1793-6 [6]):

This European Standard describes a test method for determining the intrinsic characteristics of sound reflection and airborne sound insulation of traffic noise reducing devices. It can be applied in situ, i.e. where the noise reducing devices are installed. The method can be applied without damaging the surface.

The measurements results of this method for sound reflection are not directly comparable with the results of the laboratory method (EN 1793-1), mainly because the method uses a directional sound field, while the laboratory method assumes a diffuse sound field. Moreover, this method introduces a specific quantity, called reflection index, to define the sound reflection in front of a noise reducing device, while the laboratory method gives a sound absorption coefficient. Laboratory values of the sound absorption coefficient can be converted to conventional values of a reflection coefficient taking the complement to one. In this case, research studies suggest that a quite good correlation exists between laboratory data, measured according to EN 1793-1 and field data, measured according to EN 1793-5 and EN 1793-6.

Figure 3: In-Situ measurements (EN 1793-6)

SonoCat Measurement Device [6]

All current methods to measure the sound absorption coefficient rely on assumptions for the global sound field impinging on the material under investigation. However, the capacity of a material to absorb sound depends on the sound source as well as on the environment. Acoustic engineers know how much a material absorbs normal incident sound waves, measured in a laboratory, but not for oblique incident sound waves on site.

Essentially, acoustic engineers now lack means to measure how efficient materials are used to absorb the actual sound field in the application. A similar reasoning holds for measurement of sound transmission and sound power.

Figure 4: SonoCat measurement probe

The Sonocat measurement device does not rely on any assumption for the global sound field impinging on the absorbing materials. Therefore, this method can always be used, however complex the sound field may be. It is not necessary to bring the material to a laboratory, the measurement equipment can be applied in the actual sound field. There is no need for an impedance tube, alpha-cabins or other in-situ measurement methods that only determine the absorption coefficient for normal incident plane or spherical waves.

The Sonocat's acoustic probe consists of 8 MEMS microphones positioned closely to each other. It is used to collect all the acoustic data needed to calculate the absorption, intensity or transmission, where a single microphone does not provide enough information. Using the Sonocat, the measurement area is scanned and a (spatially) averaged absorption value is obtained.

Measurement Program

To investigate the relation between the results of the measurements previously described, a measurement program has been performed. A test setup has been realized on which the acoustic insulation has been measured by all three measurement methods.

The test setup was realized in 6 different variants. This provided a set of measurement data from low- to high insulating surfaces.

The following variants are used in the measurement program:

- 6 mm MDF (~ 4.5 kg/m^2)
- 12 mm MDF (~ 9 kg/m^2)
- 24 mm MDF (~ 18 kg/m^2)
- 36 mm MDF (~ 27 kg/m^2)
- 54 mm MDF (~ 41 kg/m^2)
- 6 mm MDF – 44 mm Rockwool – 6 mm MDF (construction with a cavity)

Figure 5: Measurement setup used in this research program

Results

Overall Level

As can be seen in figure 6 there is a good correlation on overall levels between the in-situ measurements and Sonocat measurements on one side and the laboratory measurements on the other side. Although there are differences in overall levels (which was already known from the QUIESSST project) all measurement methods are able to distinguish the different variants for their insulating properties. Based on the available results the following relations (on overall levels) for the measurement methods are found:

- $DL_{SI(1793\text{-}6)} = 1.1429 \cdot DL_{R(1793\text{-}2)} + 0.5826$
- $DL_{SonoCat} = 0.9559 \cdot DL_{R(1793\text{-}2)} + 3.3729$

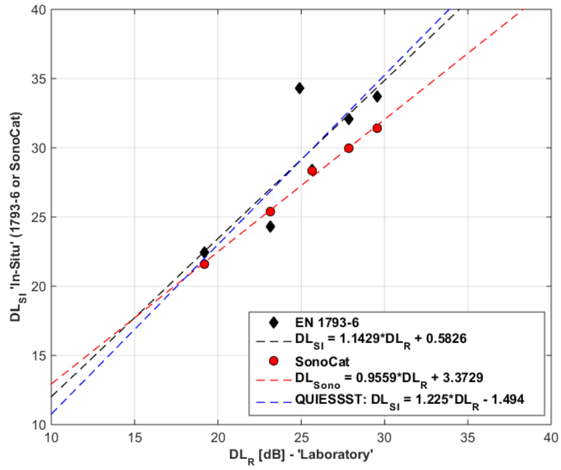

Figure 6: Results on overall levels

It can be seen that the results of the In-Situ measurements with the EN 1793-6 method fit exactly within the relation found in the QUIESSST project. The results with the SonoCat system also fit within the accuracy of this relation, but there is a clear difference in the directional coefficient of the relation.

Spectral Results

Also the insulation spectra (one third octave bands) are analysed. In this paper two typical results are shown (variants of 12mm and 54mm MDF, figure 7 and 8). It can be seen that the overall view gives a good match between the three measurement methods. For the thin variant (12mm MDF) there is some offset for the higher frequencies. This is most likely due to some leakage in test sample used for the laboratory measurements. This effect is smaller for the variant with 54mm MDF.

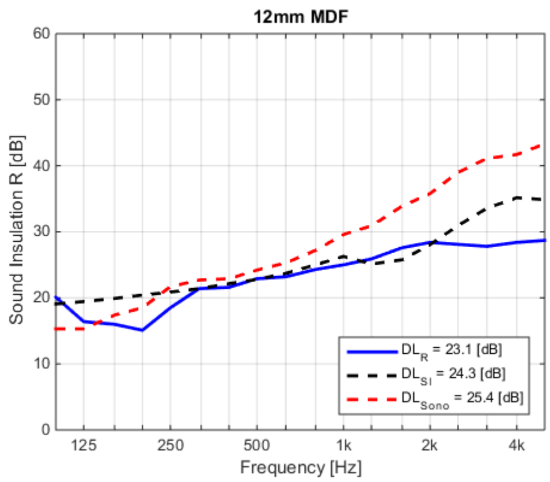

Figure 7: Spectral results for 12mm MDF

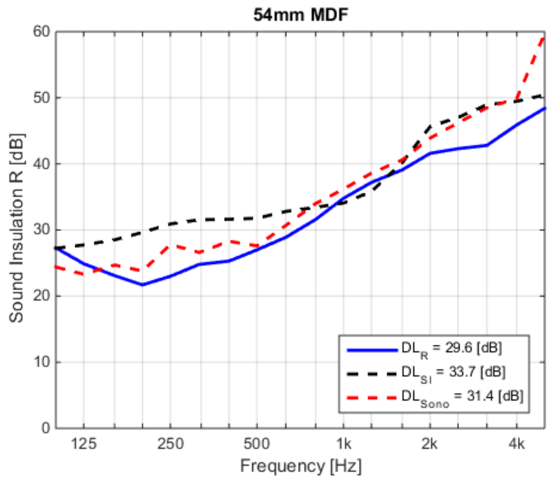

Figure 8: Spectral results for 54 mm MDF

Conclusions

The following conclusions can be drawn from the results within this research project:

- There are differences between in-situ / Sonocat measurements and laboratory measurements. This was already known from previous research (QUIESSST);
- The relation between in-situ and laboratory matches found within this project matches with QUIESSST results on overall levels;
- Spectral there are some differences;
- The Sonocat measurement system is able to detect local effects (scanning vs. local measurements);
- Laboratory measurements are very sensitive for leakage.

References

[1] EN 1793-1, "Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 1: Intrinsic characteristics of sound absorption", 2012;

[2] EN 1793-2, "Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 2: Intrinsic characteristics of airborne sound insulation under diffuse sound field conditions", 2012;

[3] EN 1793-3, "Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 3: Normalize traffic noise spectrum", 1997;

[4] EN 1793-5, "Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 5: Intrinsic characteristics – In situ values of sound reflection under direct sound field conditions", 2015;

[5] EN 1793-6, "Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics of airborne sound insulation under direct sound field conditions", 2012;

[6] http://www.soundinsight.nl/producten/the-sonocat/

[7] EN-ISO 10140-2, "Acoustics - Laboratory measurement of sound insulation of building elements - Part 2: Measurement of airborne sound insulation", 2010;

[8] EN-ISO 10140-4, "Acoustics - Laboratory measurement of sound insulation of building elements - Part 2: Measurement procedures and requirements", 2010;

[9] ISO 354, "Acoustics – measurement of sound absorption in a reverberation room", 2003