Acoustic Condition of New Noise Barriers

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Introduction

Noise barriers are used to shield immission sites, such as residential buildings, from unwanted noise and thus represent an important tool for the protection from traffic noise. However, until now there is only limited data about the real-world acoustic condition of newly installed noise barriers at roads in Germany. Within the present additional technical contract conditions and guidelines for the construction of noise barriers at roads, ZTV Lsw 22 [1], the acoustic product certification for non-reverberant environments is based on measurement methods that enable an application in situ. Utilizing these methods for the determination of the airborne sound insulation and the sound reflecting properties, this publication presents an extensive metrological survey of the acoustic condition of newly installed noise barriers in Germany.

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The author is solely responsible for the content.

Literature Review

The requirements regarding new noise barriers in Germany are summarised in [1] and E DIN EN 14388 [2]. With reference to practically dominant non-reverberant ambient conditions, the product qualification according to [1] is defined based on the in-situ measurement methods for the airborne sound insulation and the sound reflection described in DIN EN 1793-6 [3] and DIN EN 1793-5 [4] respectively. For an effective rating and comparison of the spectral sound insulation index SI and the spectral sound reflection index RI, a single value is computed with a weighting based on the standardised traffic noise spectrum defined in DIN EN 1793-3 [5]. In terms of the airborne sound insulation, a minimum single value of the sound insulation index DL_{SI} of 28 dB is defined in [1]. For the sound reflecting properties, three different categories are specified in [1] – reflecting, reflection reducing and strongly reflection reducing – which are based on the single value of the sound reflection index DL_{RI}. Depending on the application, the noise barrier of interest must satisfy the respective requirement for the intended category of sound reflection.
The requirements from [1] can be used as a baseline to evaluate the acoustic condition of new noise barriers in situ. Additionally, manufacturers now must provide certificates, including the single values for the sound insulation index and the sound reflection index, which can be directly compared to the in-situ results of the subsequent measurement campaign.

To be able to reliably record the acoustic condition of newly installed noise barriers within the measurement campaign, potential acoustic weak points were investigated through literature studies and direct contact with manufacturers and contractors. This focused on non-visible defects and irregularities of building materials, components and the result of the installation of the new noise barriers.
In summary for all types of noise barriers, particularly the area of the posts is worth to be examined in detail due to possible leakages between elements and posts of the newly installed noise barriers. Furthermore, the connections of the elements of the noise barriers towards the concrete bases and towards the ground should also be considered. Depending on the construction method of the noise barriers, further acoustic weak spots can occur. Thus, in the case of aluminium noise barriers, the coupling points between the individual cassettes should be examined [6]. At concrete noise barriers, the absorption elements should be checked for fluctuations of the sound absorbing properties resulting from the mostly manual compaction processes. Wooden noise barriers should be measured a few weeks after completion, as the airborne sound insulation varies significantly due to the drying processes of the wood immediately after installation [7].

Acoustic Measurements

In preparation of an acoustic measurement campaign, suitable sites for the acoustic investigation of airborne sound insulation and sound reflection were researched and determined. A total of ten noise barriers that are suitable for the measurements and were built within the last five years were identified by analysing building databases as well as by direct contact with clients, e.g. Autobahn GmbH, to ensure that noise barrier manufacturers or contractors had no influence on the selection. The chosen measurement locations are divided into three respective noise barriers made of concrete and aluminium and two respective noise barriers made of wood and polymethyl methacrylate (PMMA). The locations of these noise barriers are spread throughout Germany to ensure they were made by different manufacturers and installed by different contractors.

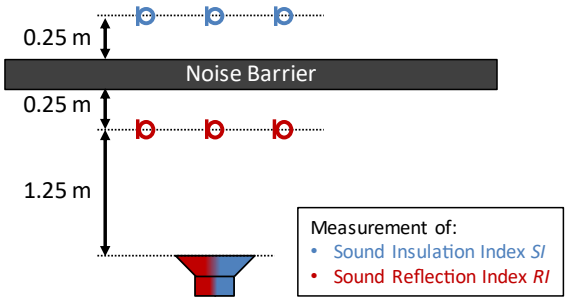

Figure 1: Schematic test setup for the simultaneous determination of the airborne sound insulation and the sound reflection properties of noise barriers in situ.

The airborne sound insulation was then determined in situ based on [3] while the sound reflection was determined in situ in accordance with [4]. All measurements were performed by means of the measuring system AcoustiAdrienne developed by AED as shown in **Figure 2**. To carry out the measurement campaign efficiently, the standard measurement method for determining the airborne sound insulation was slightly modified so that both measurements could be carried out simultaneously. The schematic measurement setup on a noise barrier is shown in **Figure 1**. The influence of this modification to the measurement setup on the results was determined within preliminary tests to be less than 0.8 dB.

Figure 2: Test setup of the measuring system AcoustiAdrienne of AED at a noise barrier made of aluminium.

The utilised measurement setup accelerated the measurement procedure so that measurements could be carried out at a total of 20 relevant measurement points at the elements and in the area of the posts at each noise barrier. As a result, the spectral sound reflection index RI and the associated single value DL_{RI} were determined at a total of 100 elements while the spectral sound insulation index SI and the associated single value DL_{SI} were measured at 100 elements and 100 posts, distributed over ten noise barriers of different designs and construction materials.

Results

Within the evaluation of the measurement results, the overall acoustic effect of the noise barriers was determined as the energetic average of the results at the individual measurement points. This represents the effectiveness of the noise barrier on the immission sound pressure level behind the noise barrier for road traffic passing with constant speed. Exemplary, **Figure 3** and **Figure 5** show the energetic averages relevant for the assessment of the complete noise barriers and the corresponding range of measured values for the three aluminium noise barriers that were investigated. An overview of the average single values DL_{SI} and DL_{RI} together with the associated standard deviations between the individual elements and posts of all tested noise barriers is given in **Table 1** and **Table 2** respectively.

To better evaluate the deviations between individual measurement points, the repeatability of the measurements was also analysed, by repeating the measurement process including the positioning of all components on the same element and post of a noise barrier. In total eight repetitions per point carried out over two days were analysed and showed a standard deviation of the repeatability for DL_{SI} of 0.23 dB at the elements and 0.26 dB at the posts, which is better than indicated in [3], but in good agreement with other recent studies [8]. For the single value of the sound reflection index DL_{RI} the standard deviation of the repeatability was determined to be 0.16 dB.

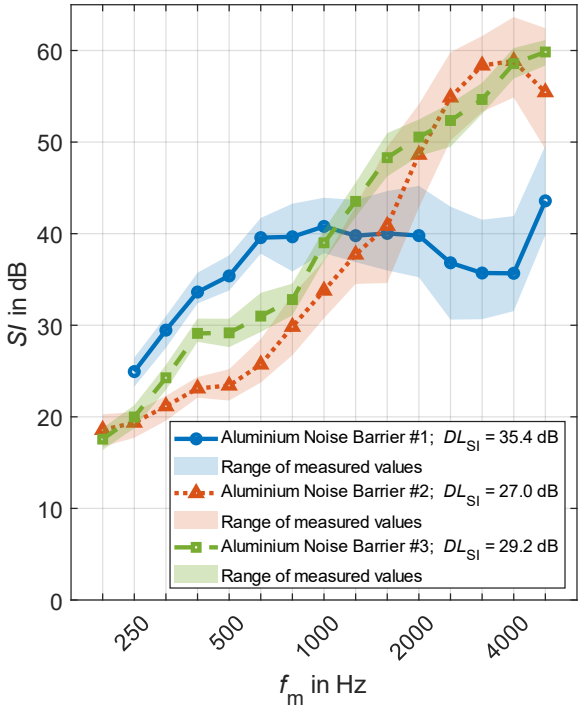

Figure 3: Energetic average and range of measured values of the spectral sound insulation index SI of the three noise barriers made of aluminium that were investigated in the project

The overall effectiveness of the noise barriers was compared with the requirements given in [1] as well as with the target values from test certificates provided by the manufacturers in case these were available.

Overall, a good initial acoustic condition regarding the airborne sound insulation of the analysed noise barriers was shown. Negative deviations of the determined single value DL_{SI} for the overall structures were smaller than 2 dB compared to the manufacturer's target values, while only one noise barrier examined showed an airborne sound insulation of 1 dB below the minimum value according to [1].

The highest average airborne sound insulation with single values DL_{SI} around 50 dB was determined at the noise barriers made of concrete due to their high mass. The deviation between the results at the individual elements, indicated by the standard deviation in **Table 1**, is significantly higher than the expanded uncertainty of the measurement procedure. This is partly explained by the fact that for two noise barriers made of concrete an inconsistent sealing between the base and the elements of the noise barrier was detected. The effect of the visually non-detectable defect of the sealing between element and base of the noise barriers is shown in **Figure 4**, while also proving that by shortening the

time window (to analyze the measured impulse response) and thus excluding this respective transfer path, the sound insulation of the elements is equalized.

Table 1: Energetic average of the single values of the sound insulation index DL_{SI} with the standard deviation σ between the individual measurement points for the elements (E), posts (P) and the overall result (G) for all ten measured noise barriers.

Noise Barrier	$DL_{SI,E} \pm \sigma(DL_{SI,E})$ in dB	$DL_{SI,P} \pm \sigma(DL_{SI,P})$ in dB	$DL_{SI,G}$ in dB
Concrete #1	62.5 ± 2.8	50.7 ± 6.1	53.4
Concrete #2	48.7 ± 2.6	48.8 ± 1.9	48.7
Concrete #3	48.2 ± 4.5	27.5 ± 6.0	30.5
Aluminium #1	35.3 ± 0.8	35.6 ± 1.0	35.4
Aluminium #2	28.6 ± 0.6	25.9 ± 1.2	27.0
Aluminium #3	30.4 ± 0.4	28.3 ± 0.8	29.2
Wood #1	32.8 ± 1.4	26.9 ± 1.5	28.9
Wood #2	30.6 ± 0.9	30.8 ± 1.1	30.7
PMMA #1	31.9 ± 1.8	33.4 ± 2.3	32.6
PMMA #2	33.6 ± 0.7	34.2 ± 0.7	33.9

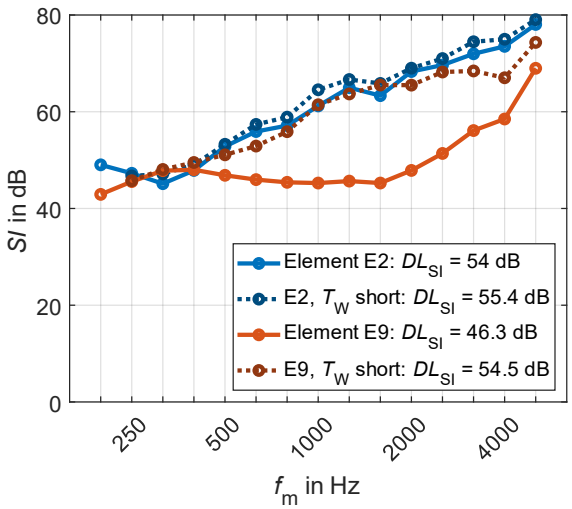

Figure 4: Measurement results of the spectral sound insulation index *SI* for two elements of a concrete noise barrier for different time window lengths to determine the influence of the inconsistently sealed joint between the base and the noise barrier element.

For the concrete noise barriers, the post areas appeared to be the weak spots in terms of sound insulation, dominating the total effectiveness of the overall wall structure. Especially in the case of the noise barrier #3 made of concrete, $DL_{SI,P}$ was on average 20 dB lower than $DL_{SI,E}$ which indicates an insufficient sealing at the joints. This noise barrier still fulfils the requirements of [1], but the potential for very high sound insulation of the heavy construction is wasted.

For the lighter noise barrier constructions, the noise barriers made of wood, aluminium and PMMA, in general lower airborne sound insulation values in the range of 27 dB to 35 dB were determined. One of these noise barriers does not meet the minimum sound insulation required in [1]. However, all of these noise barriers were still constructed according to the older ZTV Lsw 06 [9], where the requirements towards the sound insulation were both lower and based on different measurement methods. Therefore, this negative deviation from the requirements must not be overemphasized.

Despite that, some of the lightweight noise barriers show lower values for the airborne sound insulation in the area of the posts. Combined with the generally higher variability of the measured results in the area of the posts, this indicates a variable and partly not ideal sealing between the elements and posts for all types of noise barriers.

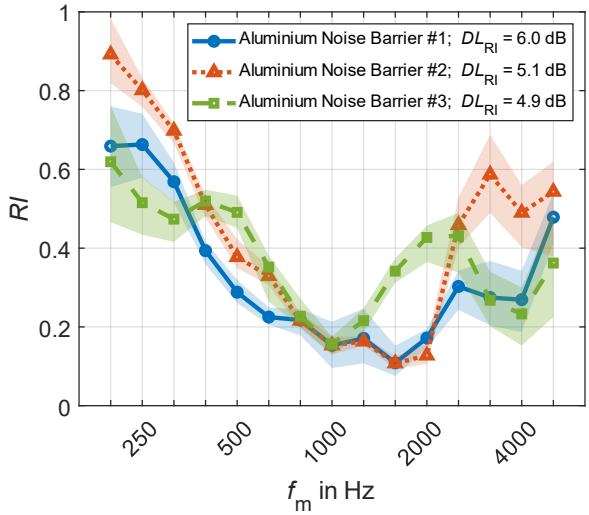

Figure 5: Energetic average and range of measured values of the spectral sound reflection index *RI* of the three noise barriers made of aluminium that were investigated in the project

Table 2: Energetic average of the single values of the sound reflection index DL_{RI} with the standard deviation σ between the results for ten different elements of the eight measured noise barriers together with the categorisation of the sound reflecting properties according to [1].

Noise Barrier	$DL_{RI} \pm \sigma(DL_{RI})$ in dB	Category according to [1]
Concrete #1	5.0 ± 0.75	reflection reducing[1]
Concrete #2	5.3 ± 0.29	reflection reducing[1]
Concrete #3	3.0 ± 0.64	reflecting[1]
Aluminium #1	6.0 ± 0.34	strongly reflection reducing[2]
Aluminium #2	5.1 ± 0.12	reflection reducing
Aluminium #3	4.9 ± 0.25	reflection reducing
Wood #1	4.7 ± 0.20	reflection reducing
Wood #2	6.2 ± 0.39	strongly reflection reducing

[1] some elements reached a higher category
[2] some elements fell into a lower category

For the sound reflecting properties, in general no significant negative deviations from the target values provided by the manufacturers were determined. In the case of the concrete noise barriers, a higher variability of the measurement results between the different elements of the noise barriers was recorded, which is likely caused by the mostly manual compaction process of the porous surface layer acting as the absorbing structure. However, when determining the reflection loss within [1], this variability is appropriately taken into account by the defined extended uncertainty.
Most of the tested noise barriers reach an average DL_{RI} that places them at the upper end category reflection reducing. These noise barriers were originally categorised as highly absorbing according to the older requirements given in [8]. However, due to the change in the measurement method and rating defined in [1] they fail to qualify as strongly reflection reducing. This represents a general challenge for the manufacturers of noise barriers and is not limited to the noise barriers investigated in this project. Therefore, the acoustic condition in terms of sound reflecting properties of all measured noise barriers was found to be good.

Summary

The research project ‘Acoustic Condition of new Noise Barriers’ analysed the initial acoustic performance of newly installed noise barriers in Germany. For that purpose, in situ measurements of the airborne sound insulation and the sound reflection were carried out. The analysis of the results was focused on identifying acoustic weak points of newly installed noise barriers as well as comparing the measured acoustic properties to the current legal requirements towards noise barriers given in [1].
In the measurement campaign, in-situ measurements of the airborne sound insulation based on [3] as well as the sound reflection in accordance with [4] were carried out at significant sections of a total of ten noise barriers of different construction types including three respective noise barriers made of concrete and aluminium each and two respective noise barriers made of wood and PMMA each. Overall, a good initial acoustic condition of the noise barriers appeared, when comparing the measurement results with the requirements of [1] as well as the manufacturers product certificates, which are based on identical measurement methods.
In addition, the distribution of the measurement results across the individual measurement points was analysed to identify potential acoustic weak spots and the probability of their occurrence. In comparison to the repeatability of the measurements, the variability of the results for different points at the same noise barrier is significant, especially for the airborne sound insulation around the posts. In conjunction with the absolute values determined at the posts, this points to a variable and often not ideal sealing between the posts and the elements of the noise barriers as the most common acoustic weak spot. Additionally, the sealing of the joints between the elements and the bases of the noise barriers were identified as a relevant acoustic weak spot in terms of airborne sound insulation at real noise barriers.
The sound reflecting properties of the investigated noise barriers showed consistent results without any significant outliers and are therefore rated as overall good.

Literature

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