Comparison between laboratory and in-situ methods for measuring sound absorption properties of noise barriers

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Summary

The REFLEX project was funded from 2013 to 2014 by the national road and rail Administrations (ASFINAG, ÖBB-Infrastruktur AG), the national Ministries for Transport and for Environment (BMVIT, BMFLUW) and federal states (Upper Austria, Styria, Carinthia, Tyrol and Vorarlberg). The project was led by the Austrian Institute of Technology AIT and involved 8 different Austrian noise barrier manufacturers as well as two scientific partners (AIT and the company TAS). The main scope of the REFLEX project was to investigate the reflection properties of different noise barriers for the specific case of the Austrian market with special attention to neighbouring countries. The research considered laboratory measurements according to EN 1793-1, in-situ measurements in the near field according to CEN/TS 1793-5 and far-field measurements in a distance of 25 meters from the barrier. The results of the laboratory method and the in-situ method were compared to the far-field results. The newly developed QUIESST method was also used to test the different noise barriers. Additionally, also BEM-simulations have been performed in order to validate the results obtained. This paper will focus only on the comparison between the laboratory method according to EN 1793-1 and in-situ methods for measuring sound reflection properties of noise barriers (according to CEN/TS 1793-5 and to the new developed QUIESST method), not only for the so-called single number ratings, but also for the frequency spectra. All analyses have been performed for the standardized noise spectrum for road traffic according to EN 1793-3as well as considering the newly proposed spectrum for railways according to FprEN 16272-3-2.

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1. Introduction

The REFLEX project was funded from 2013 to 2014 by the national Road and Rail administrations (ASFINAG, ÖBB-Infrastruktur AG), the National Ministries for Transport and for Environment (BMVIT, BMFLUW) and federal states (Upper Austria, Styria, Carinthia, Tyrol, Vorarlberg). The project was led by the Austrian Institute of Technology AIT and involved 8 different noise barrier manufacturers as well as two scientific partners.

The main scope of the REFLEX project was to investigate the reflection properties of different noise barriers for the specific case of the Austrian market with special attention to neighboring countries. The research considered laboratory measurements according to EN 1793-1 [1], in-situ measurements in the near field according to CEN/TS 1793-5 [2] and far-field measurements. The results of the laboratory method and the results of the in-situ method were compared to the far-field results. The newly developed QUIESST method [3] was also used to test the different noise barriers. In the frame of the REFLEX project also BEM-simulations have been performed in order to validate the results obtained.

This paper is focusing mainly on the comparison between the laboratory method according to EN 1793-1 [1] and the in-situ method according to CEN/TS 1793-5 [2]. As additional topic the results of the in-situ method have been compared with the results of the QUIESST method for measuring sound reflection properties of noise barriers [3]. The analyses were carried out for the so called single number ratings, as well as for the frequency spectra. The single number ratings have been calculated applying the standardized noise spectrum for road traffic according to EN 1793-3 [4] as well as considering the newly proposed spectrum for railways according to FprEN 16272-3-2 [5].

2. Method and setup

2.1 Test methods

The comparison of the results of laboratory and in-situ method is not an easy task. In the EU Project QUIESST one of the main topics of work package four was the comparison between those methods for sound insulation and for sound absorption in order to find a good correlation between laboratory and in-situ results [6, 7].

In the REFLEX project only the absorption properties were taken into account and this issue was studied with special focus to Austrian market situation. In order to compare the results of the in-situ method with the results of the laboratory method the best solution would be of course testing the same barrier in-situ as well as in the laboratory. This paper focuses mainly on the results of the in-situ measurement methods in the near-field; the results of the laboratory method were collected from the manufacturers involved in the project.

The in-situ methods taken into account were the in-situ method for sound absorption according to CEN/TS 1793-5 (also called Adrienne method) and the newly developed in-situ method for sound absorption (also called QUIESST method), which will be probably adopted as European standard EN 1793-5. This new measurement method has been presented during the last year in [3, 8]. The results have been analysed regarding spectral resolution as well as for the so called single number rating, applying not only the standard spectrum for road noise, but also considering the newly proposed spectrum for railways.

2.2 Test bench and test samples

The test bench used was a gravel pit close to Bad Wimsbach in Upper Austria, far from main transport routes inhabitants and other disturbing noise sources, where the background noise was less than 50 dB(A). Within the REFLEX project also far-field measurements have been performed, for this reason the barrier under test was composed by 5 barrier elements with a total length of 25 m. The barrier height of 4 m is based on the frequency limitation according to CEN/TS 1793-4. The barrier was installed on an 80 cm cement concrete basement. The different noise barriers considered in this study were delivered by each of the eight the manufacturers involved in the project. It is relevant to note that the barriers considered were made of different materials: aluminium, wood covering, wood-fibre concrete, synthetic materials, and also one mixed barrier mad of Plexiglas and aluminium. In addition the smooth back side of a cement concrete barrier was tested in order to have a reference barrier, which could be assumed full reflective. Figure 1 shows the 8 test sample considered in this study. The samples have been anonymised and in the present paper ware named from A to H.

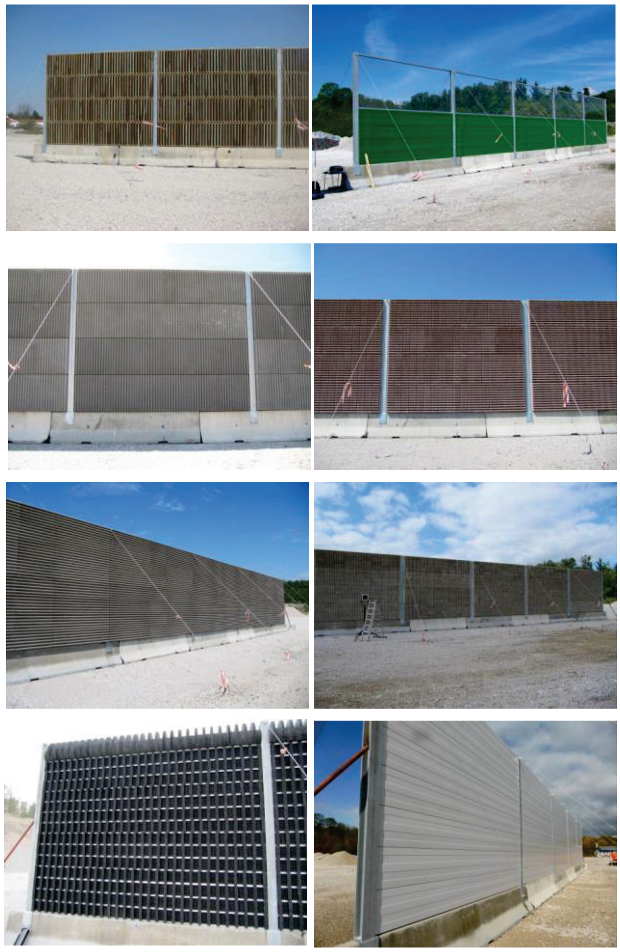

Figure 1. Noise barriers tested in the REFLEX project: the samples were anonymised and named from A to H.

3. Measurements results

3.1 Frequency spectra

Figure 2 and 3 show the frequency spectra (RI index from 200 Hz to 5 kHz) of the measurement results for all test samples from A to H including the reference barrier (black line) for in-situ method according to CEN/TS 1793-5 (Figure 2) and to the QUIESST method (Figure 3). As expected there is a similar trend for the results of both methods, only in high frequency range the QUIESST method shows constantly higher values than CEN/TS 1793-5. This effect is mainly due the directivity correction introduced with the

QUIESST method. The positive effect of this correction is also underlined by the results of the reference barrier (black line), which is nearly close to the value of RI = 1 (full reflection) for the full frequency range.

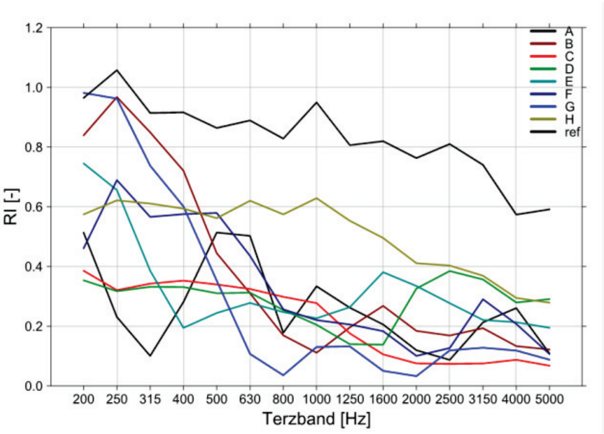

Figure 2. Measurement results: frequency spectra RI according to CEN/TS 1793-5 (test sample A to H and reference barrier ref.)

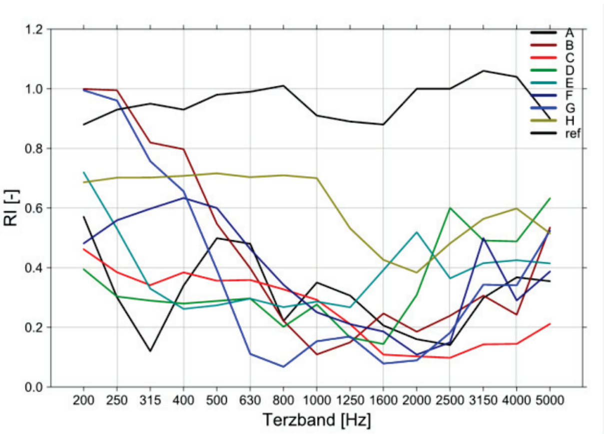

Figure 3. Measurement results: frequency spectra RI according to QUIESST (new draft standard EN 1793-5) test sample A to H and reference barrier ref.)

3.2 Single number ratings applying road and rail noise spectrum

The single number rating were calculated according to the the standard spectrum for road noise according to EN 1793-3, considering the newly proposed spectrum for railways according to FprEN 162727-3-2 for both in-situ methods. The results are presented in Table I. Due to the directivity correction the results of the QUIESST method are in general lower than the results of the CEN/TS 1793-5. It is relevant to note that with the QUIESST method the reference barrier reaches a DLRI value of 0.2 dB, which is very close to the full reflection (DLRI = 0 dB), which should be assumed for this kind of barrier.

On the other hand the application of the rail noise spectrum caused 0.2 to 1.4 dB higher values than applying the road noise spectrum. For this reason is relevant to strictly distinguish between results calculated with road spectrum and results calculated with rail spectrum, as well as between results of the QUIESST method and results of the in-situ method to CEN/TS 1793-5.

Table I. single number ratings according to CEN/TS 1793-5 and to QUIESST applying road (EN 1793-3) and rail (prEN 16272-3-2) traffic noise spectrum.

Sample	DLRI [dB] according to			
	CEN/TS 1793-5 (road)	CEN/TS 1793-5 (rail)	QUIESST (road)	QUIESST (rail)
A	5,7	6,3	5,2	5,6
B	5,2	6,1	4,8	5,4
C	6,4	7,6	5,9	6,9
D	5,9	5,7	5,5	4,9
E	5,3	5,5	4,6	4,4
F	5,3	6,0	4,8	5,3
G	6,8	8,2	5,9	6,5
H	2,7	3,1	2,2	2,5
Ref.	0,7	0,9	0,2	0,2

3.3 Comparison between single number ratings of laboratory and in-situ method for road noise

The comparison between laboratory and in-situ method was already examinated in [7]. Figure 4 show the comparison between single number ratings of the in-situ method according to CEN/TS 1793-5 and single number ratings of the laboratory methoaccoridng to EN 1793-1: the gray dots were already present in the QUIESST database, while the red dots are the additional results of the REFLEX project. As already shown bei the QUIESST project (see also Figure 4 for the statistical distribution of the single number ratings collected) the results of the in-situ method are considerably lower than the results of the laboratory method. In the REFLEX project only so called high-absoprtive barrier were considered for this comparison. The results of the laboratory method according to EN 1793-1 were between 8 and 17 dB, while the results of the in-situ method

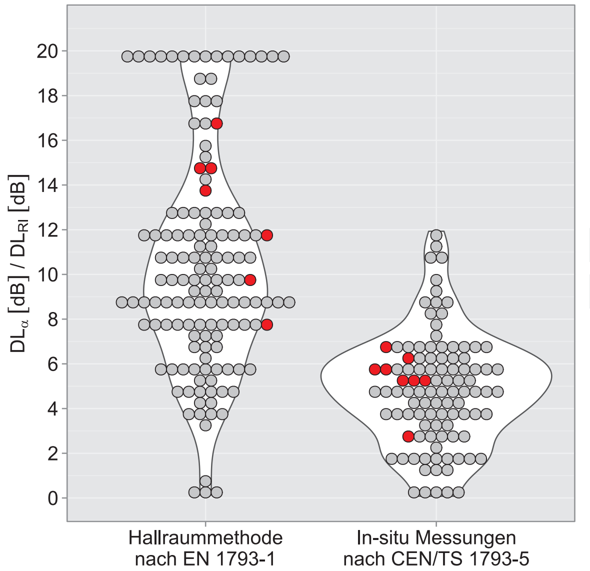

Figure 4. Comparison between single numbers according to EN 1793-1 and to CEN/TS 1793-5 based on the QUIESST database (grey dots). Red dots are from the REFLEX project. Consider the non-linear impact of the DL-scale.

according to CEN/TS 1793-5 were between 2.7 and 6.8 dB. This difference is mainly due to the differece between direct sound field present during in-situ measurements and the diffuse sound filed present in the reverbatory chamber used for the laboratory method.

4. Data analysis and correlations

4.1 Comparison between laboratory and in-situ method for single number ratings

As already shown in Figure 4 the results of the laboratory method are not direct comparable. For this reason a first attempt to try an correlation between the two methods was carried out during the QUIESST project [6, 7]. In order to get a better understanding of the relation between the results of the two methods the new data from the REFLEX project were added to the QUIESST database. Figure 5 shows an update of the correlation between those single number ratings. The correlation seems to be even worser than the correlation established during the QUIESST project (blue dots). The data from the REFLEX project only (red dots) show a completely different correlation between the two methods (due to the negative slope of the linear regression of the red dots with a correlation coefficient of 0.13). Considering both the QUIESST database and the REFLEX data the correlation becomes more feasible, in which the slope is positive and the correlation coefficient is 0.67.

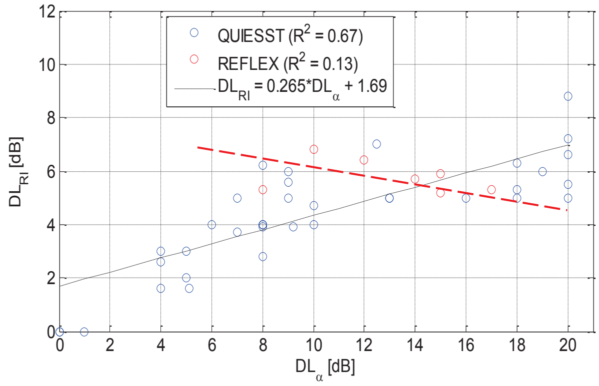

Figure 5. Correlation between single number rating of the in-situ method CEN/TS 1793-5 and the laboratory method EN 1793-1 including data form the QUIESST database (red dots are the additional results of the REFLEX project, blue dots are form the database).

Nevertheless the correlation coefficiant remains poor and therefore it is not possible to propose a conversion formula between the two methods.

4.2 Comparison between laboratory and in-situ method for frequency spectra

In order to get a better understanding of the relation between the results of the two methods it is necessary to examinate the spectra of the results. Figure 6 shows a comparison between the measured RI spectra according to the in-situ method CEN/TS 1793-5 (blue lines) and the spectral results according to EN 1793-1 for all test samples where the laboratory measurement was available (for obviously reasons the transparent reflective wall, was never tested in a reverberation chamber). It is relevant to note that in order to be compared in an easy way the absorption spectra of the laboratory method were converted into the reverse spectrum as “(1- α) spectra” (red lines). In this way for both methods the plotted values close to 0 represents high absorption properties, while values close to 1 represents high reflection properties. The frequency spectra of the test samples measured within the REFLEX project show very similar trends for in-situ results (blue lines) and laboratory results (red lines). Figure 6 shows in many cases mainly a shifting of the spectra and in some cases an ampification of the aborbing properties especially at low frequencies. In some cases the laboratory method shows values higher than $\alpha > 1$, which means more than 100% absorption. On the other hand the RI results of the in-situ method remains always between 0 and 1, excepting the reflecting back side of a concrete wall at some high frequencies (see Figure 3) and

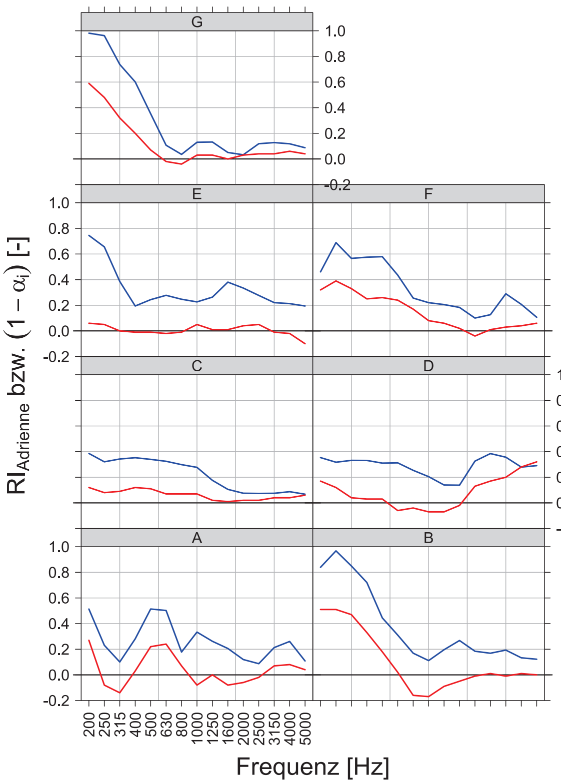

Figure 6. Comparison between frequency spectra of the in-situ method to CEN/TS 1793-5 (blue lines) and the laboratory method to EN 1793-1 (red lines, inverted and plotted as "(1- α) spectra").

therefore result in differences of the absorption properties of some test samples. This difference in the frequency spectra and the values showing absorption values higher than 100% seem to be a result of the different sound fields - diffuse sound field and direct sound field could be the main reason for the poor correlation between the two methods.

Nevertheless the consideration of a larger number of test samples could improve this correlation. In any case the correlation should be done for each third-octave band separatly.

4.3 Comparison between in-situ methods CEN/TS 1793-5 and QUIESST

The comparison between different in-situ methods was not the main topic of the REFLEX research. Nevertheless the authors decided to investigate the in-situ properties of the noise barriers considering not only the in-situ method according to the current CEN/TS 1793-5 but also applying the newly developed QUIESST method. It is relevant to note that both measurement methods were applyed by the same measurement team on the same test samples during the same measurement campaing having the same weather conditions. The comparison between those two methods is

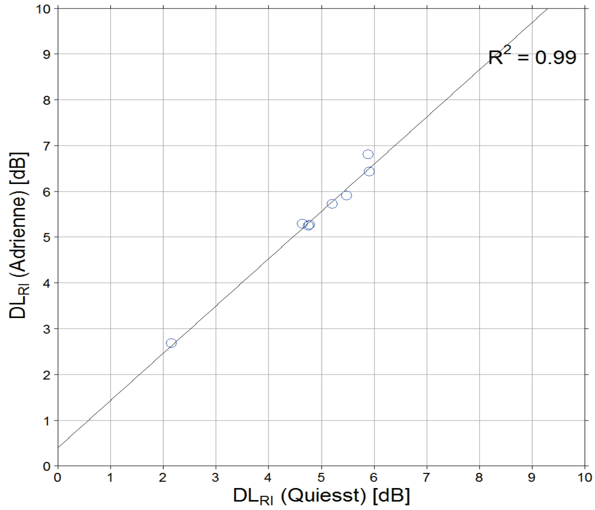

Figure 7. Correlation between single number ratings of the in-situ method CEN/TS 1793-5 and the new QUIESST method (draft standard for EN 1793-5).

based only on the test samples considered within this project. Figure 7 shows the correlation between single number ratings of the in-situ method according to CEN/TS 1793-5 and the in-situ method QUIESST, which will be probably adopted as new standard EN 1793-5. The linear regression shows a very high regression coefficient (R^2 = 0.99). The results of the QUIESST method are slightly lower the the results of the current CEN/TS 1793-5, this is mainly due to the new correction factor for loudspeaker directivity, which causes hiher values in high frequency range. In order to better investigate the differences between the two methods the frequency spectra were also analysed. Figure 8 shows the comparison between frequency spectra of the in-situ method according to CEN/TS 1793-5 and the in-situ QUIESST method for all test samples considered in the REFLEX project. The frequency spectra show a very similare trend for both methods, only at high frequencies the results of the QUIESST method are slightly higher, mainly due to the directivity correction of the loudspeaker. This leads to the fact that in general the results of the single number rating of the QUIESST method are slightly lower than the results according to CEN/TS 1793-5.

5. Conclusions

The research project REFLEX investigated typical Austrian noise barriers using the currently most relevant methods for measuring sound absorption. The results of the laboratory method according to EN 1793-1 were collected from the manufacturers, while an extensive measurement campaign has

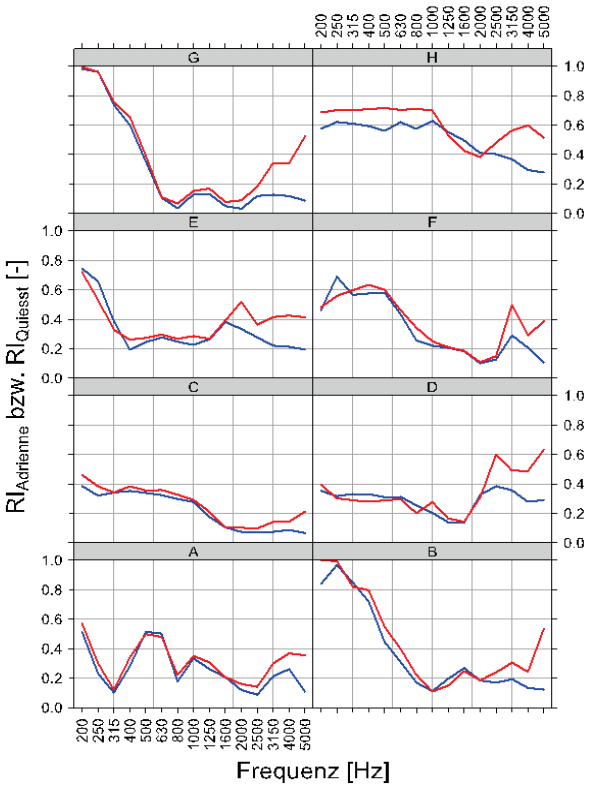

Figure 8. Comparison between frequency spectra of the in-situ method CEN/TS 1793-5 (blue lines) and the QUIESST method (red lines) for all test samples.

been carried out using the in-situ method according to CEN/TS 1793-5 as well as the QUIESST method, which will be probably adopted as EN 1793-5. As expected from the literature study the results of the in-situ method are considerable lower than the results of the laboratory method. The single number ratings of the in-situ method according to CEN/TS 1793-5 are between 3 and 7 dB, while the results of the laboratory method are between 8 and 17 dB. The poor correlation between laboratory and in-situ method found out in the QUIESST project was confirmed (R^2=0.67). This is mainly due to the different sound fields used and probably some unspecified absorption properties of some test samples, which result in α-values higher than 1. Nevertheless the frequency spectra of the test samples measured within REFLEX show very similar trends for in-situ and laboratory method and could be used as a basis for more detailed analysis. The single number ratings were calculated for the road noise spectrum as well as for the rail noise spectrum. The results weighted with the rail spectrum are in general 0.2 to 1.4 dB higher than the results weighted with the road spectrum. Concerning the relation between single number ratings according to CEN/TS 1793-5 and to QUIESST a very high correlation coefficient could be found out (R^2 = 0.99). The frequency spectra show very similar trends for both methods; only in high frequency range the RI-values of the QUIESST method are slightly higher, which is mainly due to the new correction factor for loudspeaker directivity. This means that in general the single number ratings of the QUIESST method are generally slightly lower than the values according to CEN/TS 1793-5. This information should be carefully considered by all stakeholders in order to avoid misunderstandings by interpreting the results of the in-situ method. A direct use of the in-situ results as input for noise mapping and action planning is currently not possible.

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