inter·noise 2021
1–5 August | Washington, DC

SOPRANOISE – update and analysis of noise barrier database including new current results

Marco Conter[1]
Andreas Fuchs[2]
Paul Reiter[3]

AIT Austrian Institute of Technology GmbH - Center for Low-Emission Transport
Address: Giefinggasse 4, 1210 Vienna, Austria

ABSTRACT

In the frame of the SOPRANOISE project (funded by CEDR in the Transnational Road Research Program 2018) work package 2 focused first on providing theoretical and practical background information on measurement of the acoustic performance of noise barriers due to a state-of-the-art regarding correlations and possible trends between diffuse (EN 1793-1 [1], EN 1793-2 [2]) and direct sound field methods (EN 1793-5 [3], EN 1793-6 [4]). After that, the objective of this research was to extend and update the database of the European noise barrier market developed during the QUIESST project, including more detailed analyses on single-number ratings as well as third-octave band measurement results. The data collected and the analysis performed show relevant facts and figures about acoustic performances of noise barriers measured under diffuse and direct sound field conditions, together with a better understanding of the respective significance, similarities and differences of these standardized methods, improving data analysis and correlations between these methods. This paper gives a general overview of the data collected, summarizing the main results of the statistical analyses performed. Overall results and comparisons between results of measurements performed under diffuse and under direct sound field conditions are shown. Finally, conclusions and possible outlook of the research are presented.

1. INTRODUCTION

The general objective of work package 2 (WP2) was to provide both theoretical and practical background information on measurement methods of the acoustic performance of noise barriers. The main topic of the present paper is to present the first part of the results of task 2.2 of the SOPRANOISE project. The second part of the results will be presented in a separate contribution.

As a background information, it is worth to recall the general framework of work package 2: first a systematic research on the state-of-the-art regarding physical background, available comparisons, correlations and possible trends between measurement results of methods under diffuse sound field conditions and methods under direct sound field conditions was performed. The results of this work have been summarized in the report D2.1 [5] on the “Review of the physical significance of EN 1793-1, -2, -5 and -6”. This report will be available on the project website and is not part of this paper.

[1] Marco.Conter@ait.ac.at

[2] Andreas.Fuchs@ait.ac.at

[3] Paul.Reiter@ait.ac.at

Secondly, as the main objective of task 2.2 was the update and analysis of noise barrier database including new current measurements, the WP2 activities was focused on extending the relevant database of European noise barriers developed within the QUIESST project [6], including single-number ratings and third-octave band spectra from manufactured products and already installed noise barriers. This updated database aims to show facts and figures about acoustic performances obtained from measurements performed under diffuse sound field as well as direct sound field conditions, together with a better understanding of the respective significance, similarities and differences of these standardized methods. The results of this task are the main topic of this paper, while a second more specific paper with the title "Empirical study on the correlation between measurement methods under diffuse and direct sound field conditions for determining sound absorption and airborne sound insulation properties of noise barriers" will be presented in the same session. All results are presented in the report D2.2 [7], which will be also available on the project website.

Finally, within task 2.3, the effect of acoustic degradation on the global acoustic performance of noise barriers was considered in detail. The results of this work are reported in the report "Influence of acoustic degradation of noise barriers on the total noise reduction" and will be presented in a separate paper at further conferences.

2. DATA COLLECTION AND DATABASE OVERVIEW

2.1. Data collection

Starting with the database available from the past QUIESST project, during the first part of SOPRANOISE WP2 the database was completely re-designed to give a more consistent representation of the data obtained from the different measurement methods. This gives the ability for more detailed analysis with correct cross-references. The database was implemented in PostgreSQL using a locally hosted virtual machine running Ubuntu Linux 18.04. The data processing and statistical analysis were performed with the programming language Python. More details on the database structure are presented in the report D2.2.

The second relevant step in order to achieve a meaningful database was of course the data collection itself: this has a relevant role in building consistent and statistically robust results. In fact, without a good and solid data basis, the data analysis would not lead to reasonable results, and from a statistical point of view a rather large amount of data is necessary to perform a sensible analysis. In the frame of the QUIESST project a first database on acoustic characteristics of noise barriers has been developed: based on this database, the most recent data available within the Consortium have been integrated, and further analyses on the relationships between the methods have been performed.

2.2. Overview of the collected data

As of today the SOPRANOISE database contains 448 different noise barriers (different test samples) manufactured by 58 different noise barrier manufacturers or construction companies, from 9 European countries (Austria, Belgium, France, Germany, Italy, Ireland, Spain, The Netherlands and United Kingdom) considering the country where the barrier was produced, and not where the barrier was tested or installed. On the other hand, the countries involved in the data collection were Austria, Belgium, France, Italy, Ireland, Germany and Spain. The measurements collected have been performed by 39 different testing laboratories from the European countries mentioned before.

The overall amount of data collected was unexpectedly high, reaching a total of 2029 dataset entries. For the sake of completeness, it should be noted that this number includes every single reference position (as it can be analyzed separately), every single rotation (regarding CEN/TS 1793-5 [8]), and measurements performed in front of the element and measurements performed in front of the post separately (as in some cases only post or only element measurements were available). At the same time, the total number of different measurements reach the relevant value of 1503 entities, which is very promising from a statistical point of view.

Another interesting issue is the composition of the collected data regarding the measurement method available in order to get a first overview of the content. As of today the SOPRANOISE database contains 179 entries on sound absorption according to EN 1793-1, 128 entries on airborne sound insulation according to EN 1793-2, 695 entries on sound reflection according to EN 1793-5 or CEN/TS 1793-5 (considering different reference positions separately) and 501 entries on airborne sound insulation according to EN 1793-6 (combining post and element, which are part of a single measurement). Furthermore, it is worth to note that 80% of the data collected are referring to measurements performed under direct sound field conditions, while 20% of the data refers to measurements performed under diffuse sound field conditions. Therefore, based on these first rough figures it is evident that those measurement methods under direct sound field conditions (EN 1793-5 and EN 1793-6) have been applied several times during the last 15 years and are well established and frequently used in the European market.

2.3. Data available after quality check

Nevertheless, not all data were delivered with the same quality, and not all datasets have the same level of completeness. Therefore, in a further step all collected datasets have been validated. In order to perform a meaningful statistical analysis, the collected data has been evaluated in respect to: (1) completeness of the datasets collected; (2) plausibility of the results, mainly focusing on single-number ratings, but also considering effects in the third-octave band spectra; (3) cross-checking in order to avoid repetitions of same data results coming from different sources; (4) averaging of different reference positions and different rotations into one single-number rating (especially for EN 1793-5 and CEN/TS 1793-5); (5) averaging of post and element measurements for data on EN 1793-6, in order to get the global value (if not available); (6) re-calculating values of the single-number rating when all necessary frequencies were available, in order to avoid possible calculation mistakes and (7) detecting outliers. After this validation process the SOPRANOISE database contains the following relevant figures:

- 138 single-number ratings on sound absorption according to EN 1793-1;
- 72 single-number ratings on airborne sound insulation according to EN 1793-2;
- 359 single-number ratings on sound reflection according to EN 1793-5 or CEN/TS 1793-5;
- 267 single-number ratings on airborne sound insulation according to EN 1793-6 for elements;
- 244 single-number ratings on airborne sound insulation according to EN 1793-6 for posts;
- 183 single-number ratings of global values according to EN 1793-6.

The total number of validated data reaches the value of 1263 single-number ratings. This amount of validated and high-quality data can be considered as a relevant basis for the statistical analysis performed. All further statistical analyses have been performed based on those numbers.

3. OVERVIEW OF THE OVERALL RESULTS AND STATISTICAL ANALYSIS

In this chapter the single-number ratings of the measurement results collected are presented for every method separately: first the results on sound absorption under diffuse sound field conditions according to EN 1793-1, then the results on airborne sound insulation under diffuse sound field conditions according to EN 1793-2, then on sound reflection under direct sound field conditions according to EN 1793-5 or CEN/TS 1793-5 and finally the results on airborne sound insulation under direct sound field conditions according to EN 1793-6.

For all methods a first general statistical analysis on the overall data collected was performed using box plots, statistical distribution, probability function and the data results itself, while in a further step each material was analyzed separately. For the sake of simplicity these diagrams are not presented in this paper but are shown in the report D2.2.

Based on the collected data the most represented materials[4] are metal[5], timber and wood-fibre concrete[6], followed by concrete (self-supported), plastic[7] and transparent[8] material. In addition to those materials under the material category "other" some special cases are represented, for which only few elements are present in the database, like prototypes (not available on the market), earth and green barriers, gabions (improved for their sound absorbing and / or airborne sound insulation performances), and noise barriers with integrated photovoltaic panels.

3.1. Results on sound absorption under diffuse sound field conditions (EN 1793-1)

In order to have a better comprehension of the data collected a detailed statistical analysis of single-number ratings of sound absorption under diffuse sound field conditions was performed. As the data collected were always delivered from 100 Hz to 5 kHz, the full frequency range was always considered as a basis for the further analysis.

On this point it is worth to note, that there is a difference in the formula for the volume calculation in the newest version of the standard (published 2017) in comparison to the older standard (published in 2012): this difference lead to a small reduction in the single-number rating $DL_{\alpha,NRD}$. On the other hand, the data collected was mostly measured according to older version of the standard (88% of the total) and the data measured with the newest standard are concerning flat products with small volume, where the difference between new and old standard is generally less than 0.5 dB. In addition, it should be considered that the measurement uncertainty of the method under diffuse sound conditions is considerably higher than the difference between older and newest standard ($U = \pm 2.4$ dB according to EN ISO 12999-2 [9]), therefore, during the further analysis the results will be considered together.

In a first step all data were plotted in a single statistical graph divided into 3 specific diagrams (see Figure 1): here in the top diagram (1) a classical box-plot of the data is shown, representing minimum, median, maximum values as well as 25% and 75% percentile values; then in the middle diagram (2) the statistical distribution of the data is plotted using classical histograms first and the probability density function (blue line) at different values, smoothed by a kernel density estimator, is shown. In the bottom diagram (3) every single measurement result is plotted in order to have a clear view of the data, which are behind the statistical analysis and the probability distribution.

In the case of the single-number ratings on sound absorption in the diffuse sound field all data points are between 0 and 20 dB, with circa 50% of the data being between 8 and 13 dB. The median value is around 9.6 dB with a clear peak in the kernel density distribution around 9 dB, showing that the most relevant part of the data is placed between 8 and 12 dB, while a second less pronounced peak is at the maximum value of 20 dB. It should be mentioned that the single-number rating is artificially bound to the upper limit of 20 dB in the calculation procedure.

In a second step the single-number rating results have been divided into different material types according to the most common materials collected. Those diagrams are presented in report D2.2, therefore the main information regarding the different materials can be summarized as follows: metal and plastic barriers are in general between 8 and 20 dB, while timber barriers are between 4 and 12 dB, wood-fibre concrete and sound absorbing concrete (self-supporting) are more spread between 4 and 20 dB, while transparent barriers are naturally less absorptive and reach values between 0 and 4 dB, whereas the higher values are referring to mixed barriers with up to 50% of transparent material.

[4] In general, the materials have been defined according to the QUIESST classification.

[5] In this material category at least the surface layer consists of metallic material.

[6] This material category includes all wood-fibre concrete barriers, only self-supported concrete barriers have been considered separately.

[7] In this material category at least the surface layer consists of plastic material. It is relevant to note that this material category should not be confused with transparent barriers.

[8] In this material category of transparent barriers also mixed barriers have been included, where at least 50% of the barrier was declared as transparent.

3.2. Results on airborne sound insulation under diffuse sound field conditions (EN 1793-2)

In the case of the single-number rating on airborne sound insulation in the diffuse sound field according to EN 1793-2, a similar statistical analysis was performed and in this case the frequency range considered was from 100 Hz to 5 kHz.

The results according to EN 1793-2 are in between 17 and 52 dB, with circa 50% of the data being between 24 and 33 dB. The median value is around 28 dB, with a peak in the kernel density distribution around 27 dB, showing that the most relevant part of the data is placed between 24 and 34 dB, while a second less pronounced peak is at the value of 47 dB. As explained before in a first step all data was plotted in a single statistical graph divided into three specific diagrams (see Figure 2), while in a second step the single-number rating results have been divided into different material types according to the most common materials collected. Those diagrams are presented in report D2.2, therefore the main information regarding the different materials can be summarized as follows: metal, timber, plastic and transparent barriers reach in general values between 20 and 35 dB, while woodfibre concrete and concrete barriers can reach higher values from 28 up to 52 dB.

3.3. Results on sound reflection under direct sound field conditions (EN 1793-5 or CEN/TS 1793-5)

In regard to the measurement results on sound reflection under direct sound field conditions, it is relevant to mention that the older data coming from the QUIESST database were mainly measured according to the standard CEN/TS 1793-5 (also called Adrienne), which was the only method published at the time of the QUIESST project. Therefore, the results measured according to CEN/TS 1793-5 are marked with the label *Adrienne*, while the new results according to EN 1793-5 are marked with the label *QUIESST*. It is also worth to mention that, according to the Austrian project REFLEX [10] both methods are correlating very well (R^2 = 0.99) and the difference in terms of single-number ratings was between 0.5 and 0.9 dB, which is considerably less than the measurement uncertainty of the measurement method (U = ±1.35 dB according to EN 1793-5), during the further analysis the results from EN 1793-5 and CEN/TS 1793-5 will not be separated, but will be considered together.

Furthermore, as several data points according to EN 1793-5 were measured on site (i.e. not for the purpose of certification), so that several data points were related to noise barriers smaller than 4 m height or width, meaning that those data points were valid only for a restricted frequency range. As a restricted frequency range generally leads to a significantly higher single-number rating (depending on the number of missing frequencies) the analyses have been performed always for both cases: (1) considering data with different frequency ranges (meaning that all validated data were included in the analysis) and (2) considering only data with valid results over the full frequency range from 200 Hz to 5 kHz (as specified in the EN 1793-5 for the purpose of certification). For the sake of simplicity in the present paper only results for the full frequency range are shown.

In a first analysis step, all data were plotted in a single statistical diagram divided into 3 specific diagrams (see Figure 3): here the green line represents the probability density function of the data considering both methods (*Adrienne* and *QUIESST*), while the blue dots are the results according to EN 1793-5 (*QUIESST*) and the orange dots are the results according to CEN/TS 1793-5 (*Adrienne*).

The results on sound reflection under direct sound field conditions are in general between 0 and 12 dB, with very few cases below 1 dB, and very few cases above 9 dB. The minimum results are by or very close to 0 dB, which is physically understandable in the case of full reflective barriers. The maximum values of 16 dB should be considered an “ideal” case, as this was not a real product placed on the market, but a special prototype, with full absorptive properties on the surface and very high surface structure. For this reason, the best results representing real noise barriers should be considered in the range between 8 to 10 dB (excluding prototypes).

Furthermore, it is relevant to say that the diagram shows a very clear statistical distribution, with a prominent concentration of the results around 6 dB (median value), with circa 50% of data being between 4.6 and 6.8 dB. As expected, in the case of considering all frequency ranges the results tends to be slightly higher as the 50% of the data is placed between 4.9 and 6.7 dB. Due to the high amount of data, the statistical distribution and the probability function show a very consistent result.

In a further analysis step the single-number rating results have been divided into different material types according to the most common materials collected. Those diagrams are presented in report D2.2, therefore the main information regarding the different materials can be summarized as follows: the statistical distribution for metal and timber barriers is rather similar, as the most part of the values are concentrated between 3 and 7 dB, but especially metal barriers can reach values around 8 dB or in some special cases even 10 to 12 dB. Other materials like concrete and wood-fibre concrete have a more widespread distribution, ranging from values close to 0 to 10 or even 12 dB for special prototypes. For the other materials and for plastic the range can be also very different, from values close to 0, to values around 9 to 10 dB. Transparent material barriers are naturally less absorptive and reach values between 0 and 4 dB, whereas the higher values are referring to mixed barriers with up to 50% of transparent material.

3.4. Results on airborne sound insulation under direct sound field conditions (EN 1793-6)

Also in this case it relevant to say that several data points according to EN 1793-6 were measured on site and not only for certification purposes, several data points were related to noise barriers smaller than 4 m height or width, meaning that those data points were valid only for a restricted frequency range. As a restricted frequency range generally leads to a significantly higher single-number rating (depending on the number of missing frequencies) the analyses have been performed always for both cases: (1) considering data with different frequency ranges (meaning that all validated data were included in the analysis) and (2) considering only data with valid results over the full frequency range from 200 Hz to 5 kHz (as specified in the EN 1793-6 for the purpose of certification). For the sake of simplicity in the present paper only results for the full frequency range are shown.

In a first step all data was plotted in a single statistical diagram divided into three specific diagrams (see Figure 4): the green line represents the probability density function of the data considering all data (element and post values), while the blue dots are the results measured in front of the element while the orange dots are the results measured in front of the post. In the case of the single-number rating on airborne sound insulation under diffuse sound field conditions all data are in between 10 and 67 dB, with circa 50% of data being between 25 and 37 dB. The median value of the data is around 32 dB, with a peak in the kernel density distribution around 32 dB, showing that the most relevant part of the data is placed between 25 and 35 dB, while a second less pronounced peak is at the value of 55 dB.

It is relevant to note that the number of the element measurements is not equal to the number of post measurements and the global values, as some barriers have been measured only at the element or only at the post. So, the global values could only be calculated only in the cases where both measurements (acoustic element and post) were available.

In a further analysis step the single-number rating results have been divided into different material types according to the most common materials collected. Those diagrams are presented in report D2.2, therefore the main information regarding the different materials can be summarized as follows: the single-number ratings for metal barriers (element) are in general quite narrow between 25 dB and 40 dB, while timber can be more spread between 15 dB and 42 dB. Transparent, plastic and concrete barriers reach in general higher values between 30 and 45 dB. Wood-fiber concrete are the most scattered material, as the values can range from a minimum of 15 dB up to 66 dB.

On this point, it is worth to remember that for the acoustic property of airborne sound insulation under direct sound field conditions the installation process is a relevant issue in order to have a noise barrier working properly, as several mistakes in the noise barrier installation can have a severe impact on the airborne sound insulation characteristic of the noise barrier on site.

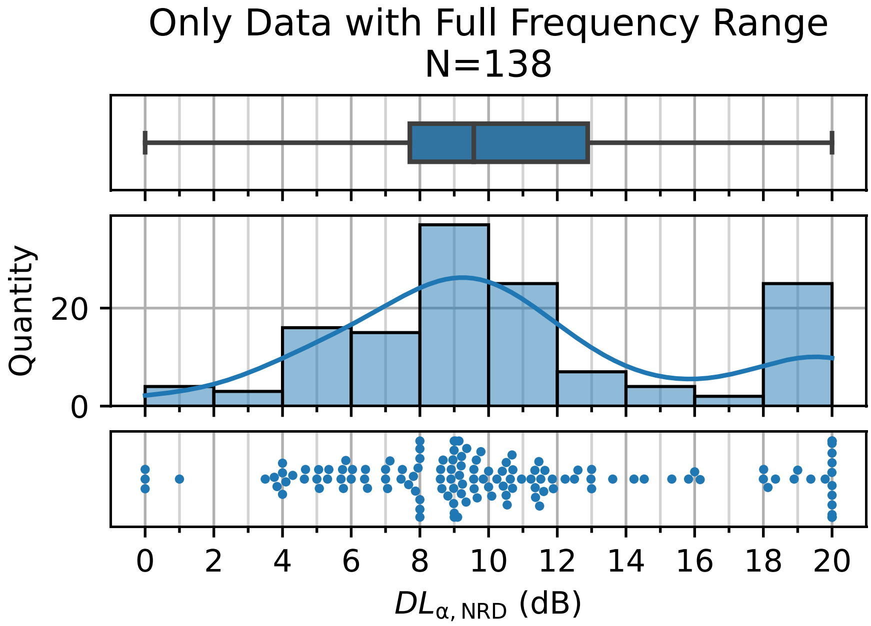

Figure 1: Statistical analysis of the single-number rating on sound absorption according to EN 1793-1: (1) box-plot of the data representing minimum, median, maximum value as well as 25% and 75% percentile values (top diagram); (2) histograms representing the statistical distribution of the data and the probability density function (blue line) at different values smoothed by a kernel density estimator (middle diagram); (3) single measurement results (bottom diagram).

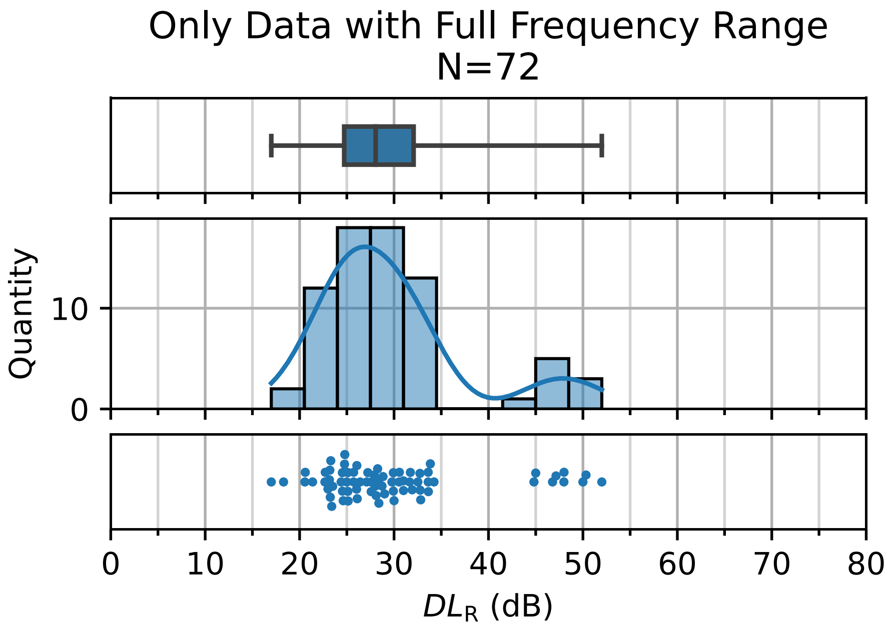

Figure 2: Statistical analysis of the single-number rating on airborne sound insulation according to EN 1793-2: (1) box-plot of the data representing minimum, median, maximum value as well as 25% and 75% percentile values (top diagram); (2) histograms representing the statistical distribution of the data and the probability density function (blue line) at different values smoothed by a kernel density estimator (middle diagram); (3) single measurement results (bottom diagram).

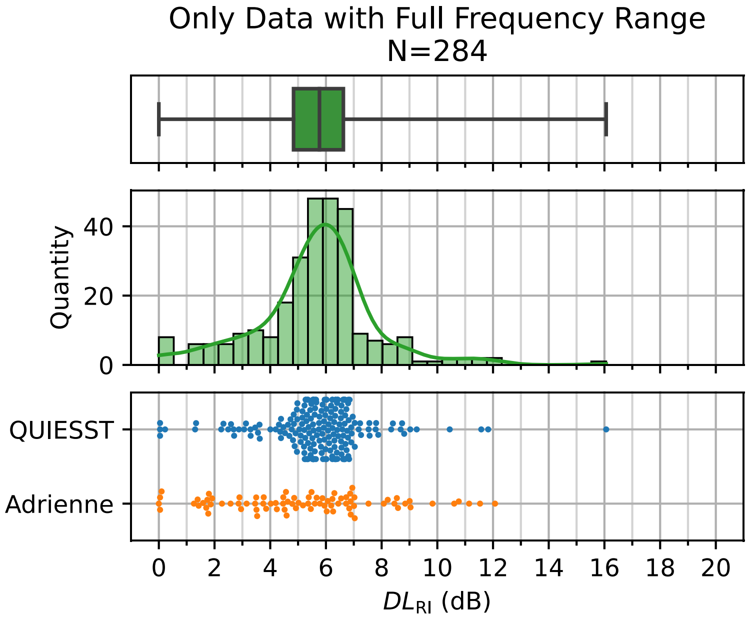

Figure 3: Statistical analysis of the single-number rating on sound reflection under diffuse sound field conditions according to EN 1793-5 or CEN/TS 1793-5: (1) box-plot of the data representing minimum, median, maximum value as well as 25% and 75% percentile values (top diagram); (2) histograms representing the statistical distribution of the data and the probability density function (green line) at different values smoothed by a kernel density estimator (middle diagram); (3) single measurement results (bottom diagram), the blue dots are the results according to EN 1793-5 (*QUIESST*) and the orange dots are the results according to the CEN/TS 1793-5 (*Adrienne*).

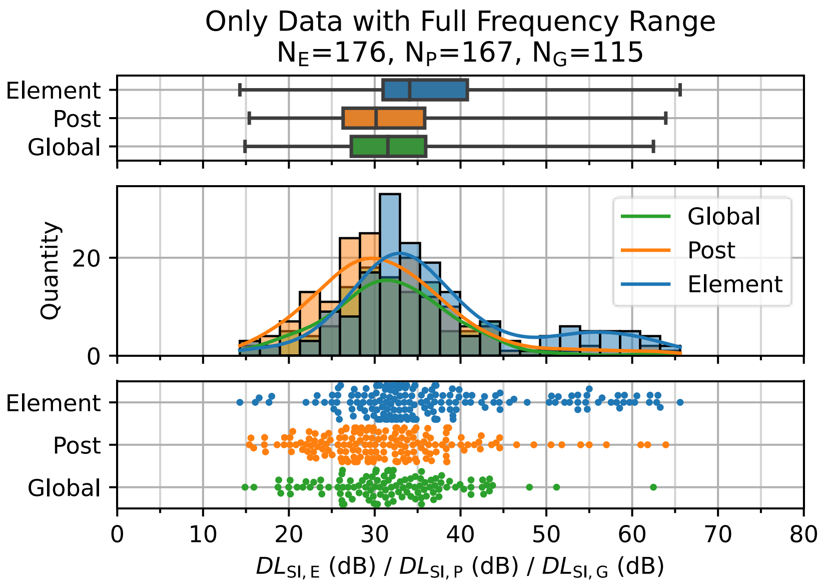

Figure 4: Statistical analysis of the single-number rating on airborne sound insulation according to EN 1793-6: (1) box-plot of the data representing minimum, median, maximum value as well as 25% and 75% percentile values respectively for “element”, “post” and “global” values (top diagram); (2) histograms representing the statistical distribution of the data and the probability density function (blue, orange and green lines respectively for “element”, “post” and “global” values) at different values smoothed by a kernel density estimator (middle diagram); (3) single measurement results (bottom diagram), the blue, orange and green dots are the results respectively for “element”, “post” and “global” values.

4. COMPARISON BETWEEN SINGLE-NUMBER RATING RESULTS

In this chapter a first comparison between single-number ratings of measurements collected is presented: first the results on sound absorption under diffuse sound field conditions (EN 1793-1) will be compared to the results on sound reflection under direct sound field conditions (EN 1793-5 or CEN/TS 1793-5), then the results on airborne sound insulation under diffuse sound field conditions (EN 1793-2) will be compared to the results on airborne sound insulation under direct sound field conditions (EN 1793-6). For both comparisons, a first general statistical analysis on the overall data collected was performed using box plots, statistical distribution, probability function and the data results itself, while in a further step each material was analyzed separately. The diagrams regarding the different materials are not part of this paper, therefore they are presented in report D2.2.

4.1. Comparison between results on sound absorption under diffuse sound field conditions and results on sound reflection under direct sound field conditions (EN 1793-1 vs. EN 1793-5)

Regarding the comparison between EN 1793-1 and EN 1793-5 (or CEN/TS 1793-5) a statistical analysis of the data collected was performed. Figure 5 shows the statistical distribution of the single-number rating results on sound absorption in the diffuse field according to EN 1793-1 and the results on sound reflection according to EN 1793-5 or CEN/TS 1793-5. The grey areas represent the probability density function of the data smoothed by a kernel density estimation, while the colored dots represent the measurement results, divided into different materials. This figure shows only data where the full frequency range from 200 Hz to 5 kHz is available, while N is the number of datasets considered for each method.

The statistical distributions clearly show that values obtained with the method according to EN 1793-1 are in general considerably higher (in several cases up to maximum value of 20 dB) than the values obtained with the methods according to EN 1793-5 or CEN/TS 1793-5. The median value for the method according to EN 1793-1 is between 9 and 10 dB, while for the method according to EN 1793-5 the median value is around 6 dB. Also, the shape of the probabilistic functions is rather different, as in the first case the data is more spread and has a second peak on the maximum value, while in the second case the data is more focused between 4 and 8 dB.

On this point it is worth to mention that for sound absorption under diffuse sound field conditions, due to the calculation formula of the single-number rating the maximum reachable value is 20 dB. Therefore, applying the method according to EN 1793-1 several noise barriers reach the maximum value of 20 dB, while the values obtained with the method according to EN 1793-5 are generally lower with only few samples reaching values between 8 and 12 dB. Also, in this case, due to the large amount of data considered, the statistical distribution and the probability function show a very consistent result.

4.2. Comparison between results on airborne sound insulation under diffuse sound field conditions and results on airborne sound insulation under direct sound field conditions (EN 1793-2 versus EN 1793-6)

Regarding the comparison between EN 1793-2 and EN 1793-6 a statistical analysis of the data collected was performed. Figure 6 shows the statistical distribution of the single-number rating results on sound insulation in the diffuse field according to EN 1793-2 and the results on sound insulation according to EN 1793-6. The grey areas represent the probability density function of the data smoothed by a kernel density estimation, while the colored dots represent the measurement results, divided into different materials. This figure shows only data where the full frequency range from 200 Hz to 5 kHz is available, while N is the number of datasets considered for each method.

The statistical distributions show clearly that values obtained according to EN 1793-2 are in general slightly lower than the values obtained according to EN 1793-6. Element values are in general higher than the results on the post, while the global values are between those values. The median value for the method according to EN 1793-2 is around 28 dB, while for the method according to

EN 1793-6 the median values are around 34 dB for measurements at the acoustic element, 30 dB for measurements at the post and 31 dB for the global values. Furthermore, the shape of the probability functions is rather similar, nevertheless the values according to EN 1793-6 can reach higher values up to 66 dB (especially at the element), while the values according to EN 1793-1 reach maximum values around 50 dB.

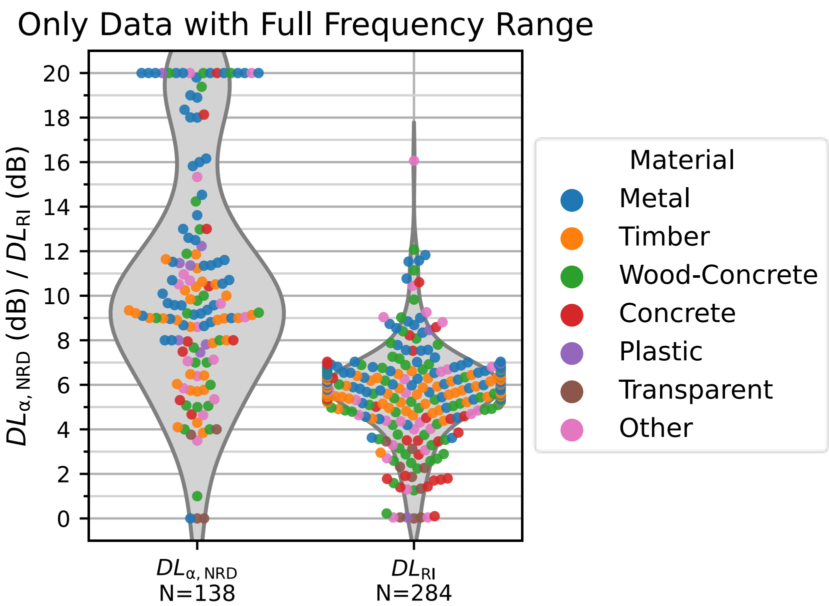

Figure 5: Comparison between single-number rating results on sound absorption according to EN 1793-1 (left) and results on sound reflection according to EN 1793-5 or CEN/TS 1793-5 (right). The colored dots represent the measurement results, divided into different materials, while the grey areas are the probability density function of the data smoothed by a kernel density estimation.

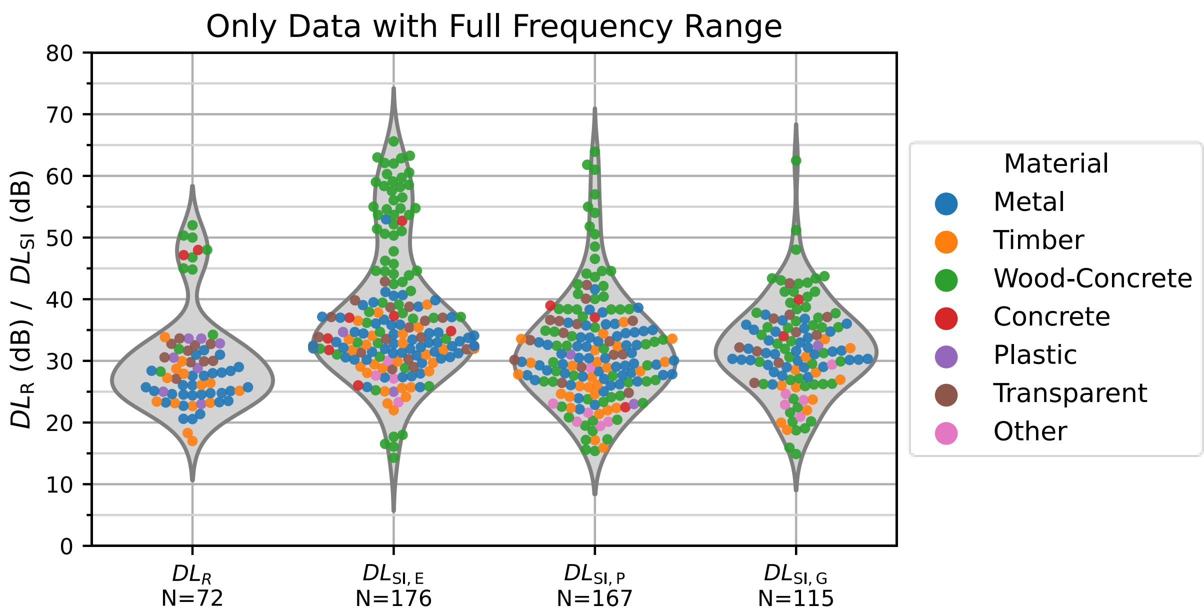

Figure 6: Comparison between single-number rating results on airborne sound insulation according to EN 1793-2 (left) and results on airborne sound insulation according to EN 1793-6 (middle-left for “element”, middle-right for “post” and right for “global” values). The coloured dots represent the measurement results, divided into different materials, while the grey areas are the probability density function of the data smoothed by a kernel density estimation.

5. CONCLUSIONS

The main objective of task 2.2 of the SOPRANOISE project was to extend and update the database of the European noise barrier market that had been first developed within the QUIESST project. The SOPRANOISE database aims to show facts and figures about acoustic performances obtained from both the diffuse sound field and direct sound field methods, together with a better understanding of the respective significance, similarities and differences of these standardized methods, improving data analysis and correlations between these methods.

The SOPRANOISE database contains now results on 448 different noise barriers manufactured and installed by 58 different noise barrier manufacturers or construction companies, from 9 different European countries (Austria, Belgium, France, Germany, Ireland, Italy, Spain, The Netherlands, and United Kingdom). The measurements collected have been performed by 39 different testing laboratories from the European countries listed before. The overall amount of data collected was unexpectedly high, reaching a total of 2029 dataset entries, while the total number of different measurements is equal to 1503 entities, and even after an accurate data selection for quality and validation purposes the total number of data considered reaches the relevant number of 1263 single-number ratings considering the following measurement methods EN 1793-1, EN 1793-2, EN 1793-5 and EN 1793-6.

Regarding the relation between single-number rating results of sound absorption under diffuse sound field conditions $DL_{\alpha,NRD}$ (according to EN 1793-1) and single-number rating results of sound reflection under direct sound field conditions DL_{RI} (according to EN 1793-5), the statistical distribution shows clearly that values measured with the EN 1793-1 are in general considerably higher (in several cases up to maximum value of 20 dB) than the values measured with the methods according to EN 1793-5 or CEN/TS 1793- 5. This is mainly a consequence of the overestimation occurring when testing highly sound absorbing elements with the measurement method under diffuse sound field conditions (i.e.: in an assumed perfectly diffuse sound field, while it is not reached in a reverberant room). Therefore, the median value for the results according to EN 1793-1 is between 9 dB and 10 dB, while for results according to EN 1793-5 (or CEN/TS 1793-5) the median value is around 6 dB. Also, the shape of the probabilistic functions is rather different, as in the first case the data is more widespread and has a second peak at the maximum value, while in the second case the data is more focused between 4 dB and 8 dB.

Regarding the relation between single-number rating results of airborne sound insulation under diffuse sound field conditions DL_R (according to EN 1793-2) and single-number rating results of airborne sound insulation under direct sound field conditions DL_{SI} (according to EN 1793-6), the statistical distributions shows that values obtained according to EN 1793-2 are in general 2 to 5 dB lower than the values obtained according to EN 1793-6. Element values are in general higher than results at the post, while the global values are between these values. The median value for the method according to EN 1793-2 is around 28 dB, while for the method according to EN 1793-6 the median values are around 34 dB for element, 30 dB for post and 31 dB for global values. Furthermore, the shape of the probability functions is rather similar, nevertheless the values according to EN 1793-6 can reach higher values up to 66 dB (especially at the acoustic element), while the values according to EN 1793-2 reach maximum values around 50 dB.

In order to more deeply analyses the data collected and to find a possible relevant correlation between these methods, an empirical study on the correlation between the different methods was performed, in which several linear and non-linear regression models have been applied. This investigation is presented in a specific paper in the frame of the same session of this congress.

6. ACKNOWLEDGEMENTS

The work presented in this article was performed in the scope of the project SOPRANOISE funded by the Conference of European Directors of Roads (CEDR) in the CEDR Transnational Road Research Program Call 2018.

7. REFERENCES

1. EN 1793-1, “Road traffic noise reducing devices - test method for determining the acoustic performance - part 1: Intrinsic characteristics of sound absorption under diffuse sound field conditions”, CEN, 2017.
2. EN 1793-2, “Road traffic noise reducing devices - part 2: Intrinsic characteristics of airborne sound insulation under diffuse sound field conditions”, CEN, 2018.
3. EN 1793-5, “Road traffic noise reducing devices. Test method for determining the acoustic performance. Intrinsic characteristics. In situ values of sound reflection under direct sound field conditions”, CEN, 2018.
4. EN 1793-6, “Road traffic noise reducing devices - test method for determining the acoustic performance - part 6: Intrinsic characteristics - in situ values of airborne sound insulation under direct sound field conditions”, CEN, 2019.
5. A. Fuchs, P. Reiter, M. Garai and W. Bartolomaeus, “D2.1: Review of the physical significance of EN1793-1, -2, -5 and -6”, SOPRANOISE project, 2020.
6. M. Conter, M. Czuka and S. Breuss, “D4.3 & MS 4.2 - Final procedural report on WP4 activities, including public database of European NRD, data analysis and definition of NRD families”, QUIESST project, 2012.
7. M. Conter, A. Fuchs “D2.2: Acoustic assessment of the intrinsic performances of noise barriers”, SOPRANOISE project, 2021.
8. 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”, CEN, 2003.
9. EN ISO 12999-2:2020, “Determination and application of measurement uncertainties in building acoustics - Sound absorption”, CEN, 2020.
10. M. Conter and R. Wehr, “Comparison between laboratory and in-situ methods for measuring sound absorption properties of noise barriers”, Euronoise, Maastricht, 2015.