Das CEDR Projekt SOPRANOISE – Datenbank und Analyse der akustischen Eigenschaften von Lärmschutzwänden

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Abstract

Das europäische Kollaborationsprojekt SOPRANOISE, finanziert durch CEDR, die Vereinigung der Europäischen Straßenverwalter, mit dem transnationalen Forschungsprogramm 2018, befasst sich mit den Methoden zur akustischen Bewertung von Lärmschutzwänden unter realen Bedingungen.

Das Arbeitspaket 2 befasste sich zuerst mit dem theoretischen Hintergrund und den Unterschieden zwischen den Messmethoden unter diffusem Schallfeldbedingungen (Schallabsorption nach EN 1793-1 [1] und Luftschalldämmung nach EN 1793-2 [2]) und den Messmethoden im akustischen Freifeld (Schallreflexion nach EN 1793-5 [3] und Luftschalldämmung nach EN 1793-6 [4]).

Im Rahmen der Literarturstudie wurden ersten Trends und mögliche Korrelationen zwischen den Ergebnissen der oben erwähnten Messmethoden identifiziert. In einem zweiten Schritt wurde dann die im Rahmen des Europäischen Projekt QUIESST (2009 bis 2012) aufgebaute Datenbank weiterentwickelt und mit neuen und genaueren Daten aktualisiert. Darauf basierend wurden dann detailliertere Analysen durchgeführt, sowohl für die Ergebnisse der Einzahlangaben als auch für die Terzbandspektren. In diesem Beitrag wird eine generelle Übersicht über die gesammelten Daten und die Hauptergebnisse der durchgeführten statistischen Analysen gezeigt. Am Ende des Beitrages werden dann Schlussfolgerungen und mögliche Fortsetzungsarbeiten identifiziert.

Introduction

The general objective of work package 2 of the SOPRANOISE project was to provide 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 project. More details on the results of the work performed in this work package are presented in the report SOPRANOISE D2.2 [5].

Data Collection

Starting with the database available from the past QUIESST project, during the first part of work package 2 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 Post-greSQL using a locally hosted virtual machine running Ubuntu Linux 18.04.

The data processing and statistical analysis were performed with the programming language Python.

The second relevant step in order to achieve a meaningful database was a data collection: 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. Based on the past database, the most recent data available within the Consortium have been integrated, and further analyses on the relationships between the methods have been performed.

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 Nether-lands 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 analysed separately), every single rotation 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.

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) aver-aging of

different reference positions and different rotations into one single-number rating (especially for EN 1793-5 and CEN/TS 1793-5) [6]; (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 according to EN 1793-1;
- 72 single-number ratings according to EN 1793-2;
- 359 single-number ratings according to EN 1793-5 (and CEN/TS 1793-5);
- 267 single-number ratings according to EN 1793-6 for element;
- 244 single-number ratings 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.

Results

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 un-der direct sound field conditions according to EN 1793-6.

Due to the short length of this paper only a rough description of the results will be given, and no diagrams will be shown. The diagrams and all detailed analyses are presented in report D2.2.

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 analysed separately.

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 (from 2017) in comparison to the older standard (from 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 [7]), therefore, during the further analysis the results will be considered together.

In the case of the single-number ratings on sound absorption in the diffuse sound field (EN 1793-1) 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. 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.

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. The main results 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 wood-fibre concrete and concrete barriers can reach higher values from 28 up to 52 dB.

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

In regard to the 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. It is also worth to mention that, according to the Austrian project REFLEX [8] 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 was not separated and was considered together.

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 data 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. The most relevant information regarding 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.

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).

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, according to the standard, the global values could only be calculated only in the cases where both measurements (acoustic element and post) were available.

Regarding the different materials the main results 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-fibre 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 underline that especially 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.

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 Nether-lands, 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 collect-ed 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 ac-cording 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. Further-more, 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. Fore more details on this study it should be referred to report D2.2.

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