ZWICKER'S LOUDNESS MODEL AS A TOOL IN THE ASSESSMENT OF AIRBORNE SOUND INSULATION

Monika Rychtáriková[1*], Vojtech Chmelík[2], Christ Glorieux[3]
[1] KU Leuven, Department of Architecture, Campus Brussels and Ghent, Belgium.
[2] STU Bratislava, Department of Materials Engineering and Physics, Faculty of Civil Engineering, Slovakia.
[3] KU Leuven, Department of Physics and Astronomy, Laboratory of Acoustics – Soft Matter and Biophysics, Celestijnenlaan 200D, B3001 Heverlee, Belgium.

ABSTRACT

Choosing adequate single-number quantities in architectural acoustics is not straightforward and often even cumbersome. Nonlinear loudness perception combined with frequency dependence of the human hearing sensitivity makes the usage of a simple decibel scale for the description of the perceived loudness of sounds with a wide frequency range and large dynamic range (in intensity) very complicated, if not impossible. In the process of the conception and validation of single number quantities, laboratory listening tests are often used. This very appropriate approach however has its limitations concerning the number of sound stimuli and/or a number of partition constructions to be tested, within an acceptable listening test duration (when working with human subjects).

To be able to get an assessment of a single number quantity on a statistically significant number of tested wall-stimuli combinations, in this paper, an alternative method is suggested. A calculation method that determines the Loudness of sounds transmitted through partition walls is used as a tool for the assessment of the walls' airborne sound insulation. This approach removes the need for listening tests and thus allows testing many scenarios, each involving a combination between a partition wall and a real-life sound stimulus. The adequacies of recently used single number quantities and of a series of newly proposed single number quantities, are compared.

Keywords: *Loudness, Sound insulation, Single Number Quantity, Sound Perception.*

1. INTRODUCTION

During the process of architectural design and project preparation, an architect (and/or acoustic engineer) needs to make a fast decision on the choice of walls, floor or façade systems, etc, while considering many different features of each building element, such as their thermal and acoustic properties, fire safety, price, sustainability etc. In this rather complex qualitative multiparameter assessment that makes part of the design process, it is important to have a clear and simple description of the sound insulation quality, preferably by a single number.

From the point of view of acoustics, describing the sound insulation of a partition between two dwellings or building façade by only one number is rather awkward. This is because sound insulation is frequency dependent, and different constructions can have a very different frequency dependence of the sound reduction index R (dB). Another difficulty is to know, which type of noise source should be insulated. Sounds that occur in households or in the building exterior might carry very different temporal and spectral content.

Different Single Number Quantities (SNQs) have been suggested by researchers and published in scientific articles

*__Corresponding author__: monika.rychtarikova@kuleuven.be

and/or discussed at different acoustic fora. Perceptual validation of SNQ through laboratory listening tests has been identified as one of the suitable methodologies. [1]
In this contribution, we introduce recent work on this matter, which suggests to use Zwicker's Loudness as an alternative method to listening tests on perceived Loudness in building acoustic context.

2. PROPOSAL FOR NEW ASSESSMENT METHOD BASED ON ZWICKER'S LOUDNESS MODEL

In the process of SNQ validation, the biggest challenge lies in the necessity to perform a large number of laboratory-listening tests with human subjects. To obtain a statistically relevant result, a validation of a SNQ requires testing for many different wall types with multiple real-life stimuli that are representative for given scenarios. Several research efforts have been done in the past which either suffered from too little wall-types [2] or too little stimuli-types [3].
Since the most common question in listening tests relates to the perceived loudness of the transmitted sound, we propose an alternative approach, that allows for testing large number of "partition wall – real-life sound stimuli" combinations.
This approach is based on making use of well-established and generally accepted Zwicker's Loudness model [4]. In this method, instead of numerous and time-consuming listening tests, the smallness of the Loudness level of transmitted sound on the receiving side of a building element for a given sound on the sending side is considered as a quantity that reflects the isolation quality of a wall for that sent sound.
The proposed method has been elaborated and validated in 3 recent papers. [5-7]
In reference [5], a ranking of walls based on calculated Loudness was compared with results (ranking) obtained from laboratory listening tests, and with the value of single-number quantities that are commonly used for objective evaluation of the sound insulation i.e., R_w and R_w+C.
The perceptual comparison was based on real-life sounds transmitted through different types of partitions, heavy weight and lightweight walls, and combined walls.
The listening tests were based on responses from 40 test subjects. In that study, two new single-number quantities, R_{mod} and $R_{mod,2}$ were proposed.
In reference [6], we first presented the newly proposed indoor spectrum developed at CSTB France [8], and then elaborated on the Loudness of the emitted sounds. Next, we discussed the correlation between the calculated Zwicker's Loudness values and walls ranked according to different SNQs (R_w + $C_{100–3150}$, R_w + $C_{50–3150}$, R_w + $C_{100–5000}$, R_w + $C_{50–5000}$ and two new quantities $R_{w + indoorA}$ and $R_{w + indoor40}$)
Reference [7] continues along the same lines but is based on larger statistics and investigated, again based on the consistency with transmitted Loudness, new SNQs by varying the C-weighting factor. This study included 56 different wall types, 15 heavyweight, 15 lightweight, 15 combined and 11 CLT based. The used stimuli were based on real life sounds (human voices, household equipment, sounds produced by people, movie sound, music), and artificial noise (pink noise, indoor noise suggested by CSTB and 4 variants of spectra).
In this work, the concept of "normal neigbour" and "noisy neigbour" is introduced in order to adequately correlate transmitted Loudness ranking with SNQ-ranking for both moderate and high acoustic comfort conditions. Also the quantification of the correlation, on the basis of Spearman's monotonity coefficient or on the basis of goodness of a fit, is discussed.

3. CONCLUSION

Acoustic isolation assessment that uses Zwicker's Loudness model to evaluate the transmission of sound through a building element was shown to be an adequate approach, which allows to evaluate SNQs for isolation performance in a rapid and reliable way.
Nevertheless, it should be mentioned that the annoyance by neighbour's noise in dwellings or by traffic noise transmitted through the building facade involves more factors than just the transmitted sound pressure level. New research is ongoing in this context, through a PhD thesis of Michiel Geluykens [9] performed in the framework of the EU project ActaReBuild [10] as a joint PhD degree between the 3 laboratories TGM Wien, STU Bratislava [11] and KU Leuven [12].

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