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Justification of standardized level differences in rating of airborne sound insulation between dwellings

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ABSTRACT

It has long been recognized that single-number quantities R'_w, $D_{nT,w}$ or $D_{n,w}$ result in different conclusions in objective rating of airborne sound insulation between dwellings. The difference between the values of these single-number quantities (SNQ), however, does not prove which of them describes the sound transmission between rooms most correctly. The main object of this article was to study which SNQ correspond best with transmitted living sound levels in buildings when reverberation time, volume of receiving room and sound insulation are taken into account. Data of 100 field measurements of airborne sound insulation were collected as well as 207 reverberation times of furnished rooms. The transmitted sound levels of living sounds were evaluated on the basis of known living sound spectra and measured level differences *D*. The results show that the SNQs standardized to reference reverberation time of 0.5 s lead in all cases to best correlation between the SNQs and the sound levels of transmitted living sounds. It was also checked whether the rating by $D_{nT,w}$ would lead to higher transmitted sound levels of living sounds in larger rooms, but this was not detected. The use of $D_{nT,w}$ makes rooms of different volumes equal in regard to required sound insulation between them. It is thus justified to replace R'_w with $D_{nT,w}$ as the SNQ for rating the airborne sound insulation. Widening the frequency range down to 50 Hz or up to 5000 Hz did not give noteworthy improvement in the correlation.

1. Introduction

1.1. Background

There has recently been discussion about the validity of weighted sound reduction index R_w as a descriptor of sound insulation against different living sounds from neighbouring dwellings. According to two recent laboratory experiments [1–2], there is a strong correlation between R_w and occupants' subjective rating of airborne sound insulation of different walls against varying living sounds. In these studies, the measurements of R_w of walls were based on laboratory tests, where measurement conditions like volume or absorption area of the source and receiving rooms do not change.

In field measurements, the volume and absorption area of the source and receiving rooms as well as the area of the separating structure do change and, furthermore, affect the measurement result of airborne sound insulation [3]. The present standard [4] defines three basic single-number quantities (SNQ) for the rating of airborne sound insulation between rooms: weighted apparent sound reduction index R'_w, weighted normalized level difference $D_{n,w}$ and weighted standardized level difference $D_{nT,w}$. The first of the three SNQ's attempts to describe the transmission of sound power between rooms, provided that flanking sound is negligible. The other two accept the fact that the flanking sound has a significant effect on the level differences in the field. They are defined by the difference of sound pressure levels between source and receiving rooms. Normalized level difference D_n corresponds to reference absorption area A_0 of 10 m^2 in the receiving room and standardized level difference D_{nT} to reference reverberation time T_0 of 0.5 s in the receiving room [5,6].

The measurement method of sound reduction index *R* was originally developed for laboratory measurements where no significant flanking transmission is present [7,8]. Later the method has been adapted to the field measurements [9], and it is still used in them [6], albeit the term for the SNQ in the field measurements is weighted apparent sound reduction index denoted by R'_w.

It has been long recognized that R'_w, $D_{nT,w}$ and $D_{n,w}$ lead to different conclusions in objective rating of the airborne sound

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insulation between dwellings, especially when the room volume increases [3,10–12]. In a German standard of the 1950s [12], the properties of the constructions and sound insulation between rooms were clearly separated: sound reduction index was used in laboratory measurements describing the properties of a construction, and sound level differences were used describing the sound insulation between the rooms in buildings.

At the moment, more than a half of the European countries use R'_w as the primary SNQ for rating of airborne sound insulation in their building regulations. SNQs based on standardized level differences are used in the rest of the countries [13–15]. In some countries, the opinions on preferred SNQs have changed with time. For example, Finland preferred the standardized sound level differences in field measurements until 1967. After that, Finland has defined the requirements for airborne sound insulation between dwellings as R'_w [16,17].

There are also recent studies showing that the use of different SNQs such as R'_w or $D_{nT,w}$ lead to divergent interpretation of measurement results and divergent judgment of the objective acceptability of constructions [18–20]. The fact that the three mentioned SNQs are different requires research in order to study which of them is best in describing the transmission of living sounds between rooms. This kind of study should vary different living sound spectra, room absorptions, room volumes and sound insulating structures. To our knowledge, such research does not exist.

1.2. Objectives

The main objective of this study is to find out which single-number quantities correspond best with transmitted sound levels of different living sounds between rooms in field conditions when room acoustics and volume of receiving room and sound insulation between rooms are taken into account. On the basis of earlier studies [3,18–20] one might draw a conclusion that the change of SNQ from R'_w to $D_{nT,w}$ might mean that less sound insulation between rooms is required or change of SNQ might lead to higher sound levels in larger rooms. Thus, another objective is to find out whether sound level of transmitted living sound rises when room volume rises but the value of $D_{nT,w}$ is similar.

Our method to study the main objective is to collect data of level differences in field measurements of airborne sound insulation between dwellings. Reverberation times measured in dwellings were also collected in order to check how well room acoustics of Finnish apartments correspond to reference reverberation time T_0 and reference absorption area A_0 presented in the standards. The final objective of the study is to find out how much T_0 and A_0 are connected with room volume.

2. Materials and methods

2.1. Field measurements of airborne sound insulation

The transmitted sound levels of living sounds were evaluated on the basis of previously reported living sound spectra [1] and measured level differences D between furnished rooms (unpublished database). The level differences as well as reverberation times of the rooms were collected from field measurements.

The database of field measurements of airborne sound insulation in furnished rooms was made by Tampere University of Technology on the basis of field measurement results of a Finnish acoustical engineering company [21]. The measurements had been done for several reasons as a part of ordinary consultancy: older buildings were measured before alterations or because of complaints, in newer buildings, the measurements were also done because the property manager wanted to check the fulfillment of sound insulation requirements. The measurements had been done during the years 2009–2013 according to the standard ISO 140-4 [5] in the frequency range 50–5000 Hz. The buildings were constructed between 1885 and 2013. Both horizontal and vertical measurement directions were included.

The collected database involves the information of the separating construction, background noise levels at 1/3-octave bands, area of separating structures, volume of source and receiving rooms, reverberation times T measured at 1/3-octavebands in the receiving rooms, sound pressure levels L_1 in source room, sound pressure levels L_2 in receiving rooms and level differences D between source and receiving rooms. The sound pressure levels L_1 and L_2 were measured and level differences were calculated at 1/3-octave bands.

Airborne sound insulation data was collected from 100 field measurements. The volume of receiving rooms was between 15 m^3 and 142 m^3 (Fig. 1). A significant part of the receiving rooms were quite small.

2.2. Reverberation times and absorption areas

Data of reverberation times were collected from impact sound insulation measurements according to ISO 140-7 [22] in addition to airborne sound insulation measurements. Reverberation time data was available from 207 rooms the volume of which varied from 14 m^3 to 220 m^3. The absorption areas of the furnished rooms were calculated from the measured reverberation times and volumes of the rooms according to the Sabine's formula. The results were rounded to one decimal.

The Pearson's correlation coefficients of the reverberation times and absorption areas with room volume were determined and the coefficient of determination R^2 was calculated.

2.3. Single-number quantities for rating of airborne sound insulation

The measurements in the database have been done before the newest revision of standard ISO 717-1 [4] was published. The calculation of the SNQs and spectrum adaptation terms, however, was

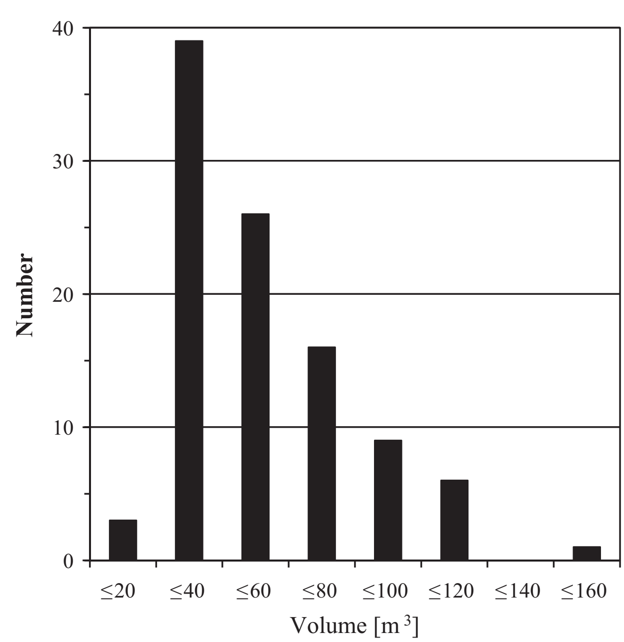

Fig. 1. The number of receiving rooms of airborne sound insulation measurements in eight volume categories.