inter.noise
HAMBURG 2016

Justification of standardized impact sound pressure levels in rating of impact sound insulation of floors

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ABSTRACT

Until 1967, Finland preferred the standardized single-number quantity (SNQ) $L'_{nT,w}$ as the measure for impact sound insulation between dwellings. After that, Finland has defined the requirements as a normalized SNQ $L'_{n,w}$. It has long been recognized that the normalized and standardized SNQs result in different conclusions in objective rating of impact sound insulation between dwellings. However, the difference between the SNQs does not prove which of them describes the transmission of impact sounds between rooms most correctly. The object of this paper was to study which SNQ corresponds best with transmitted impact sound pressure levels in buildings. The values of normalized SNQs $L'_{n,w}$, $L'_{n,w} + C_I$ and $L'_{n,w} + C_{I,50\text{-}2500}$ and standardized values $L'_{nT,w}$, $L'_{nT,w} + C_I$ and $L'_{nT,w} + C_{I,50\text{-}2500}$ were calculated on the basis of 110 field measurements. The transmitted sound pressure levels L_{eq} generated by the tapping machine were calculated, too. A correlation analysis between the SNQs and L_{eq} of the transmitted impact sounds was carried out. The analysis shows that the standardized SNQs result in higher correlations with the sound pressure levels of transmitted impact sounds. It is thus justified to replace $L'_{n,w}$ with $L'_{nT,w}$ as the SNQ for rating the impact sound insulation.

Keywords: impact sound insulation, building acoustics
I-INCE Classification of Subjects Numbers: 51.5, 81.2

1. INTRODUCTION

1.1 Background

The German standard (1) published in 1952 introduced a standardized method for measuring impact sound insulation between dwellings. The measurement method was based on the tapping machine first introduced by Gastell in 1936 (2). The standard presented two different ways for normalizing the measured impact sound pressure levels: normalization with respect to the reference absorption area A_0 and standardization with respect to the reference reverberation time 0.5 s (later T_0). By then, the standard specified that A_0 should be chosen such that it corresponds to 0.5 s at each volume of receiving room when measurements are carried out in dwellings. The A_0 of 10 m^2 was purposed only for the laboratory measurements. The calculation method for single-number quantities (SNQ) was introduced in 1953 in the German standard, too (3).

Both the German standard published in 1960 (4) and the international standard ISO/R 717:1968 (5) released in 1968 presented only evaluation of the normalized impact sound pressure levels. In both of these standards the chosen reference absorption area A_0 was 10 m^2 and no standardization of impact sound pressure levels to reverberation time was presented. The standardization was again an available method for normalization in the 1980's when the standard ISO 717-2:1982 (6) was released. Since then the ISO-standards have given the opportunity to use either normalized or standardized impact sound pressure levels and thus made possible to give impact sound insulation regulations as two SNQs: $L'_{n,w}$ and $L'_{nT,w}$. The spectrum adaptation terms C_I and $C_{I,50\text{-}2500}$ were introduced in the standard ISO 717-2:1996 (7). The terms were adopted in order to take level peaks at single frequencies and the low

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frequency impact sound pressure levels more accurately into account.

It has long been recognized that the normalized and standardized SNQs result in different conclusions in objective rating of impact sound insulation between dwellings (e.g. 8, 9). This is especially a problem when the volume of the receiving room increases and has also been noticed in the case of airborne sound insulation (10, 11). However, the difference between the SNQs does not prove which of them describes the transmission of impact sounds between rooms most correctly. In other words, it is possible that either normalized or standardized SNQ rates the impact sound insulation between dwellings incorrectly.

The normalized and standardized SNQs can rate the measurements differently due to the difference between the terms normalizing the measured impact sound pressure levels L_2 in the receiving room. The reason for this is that the relations between measured reverberation time T and the reference T_0 of 0.5 s as well as the calculated absorption area A and the reference absorption area A_0 of 10 m^2 are not always equal because of different room volumes and distributions of absorptive materials in room. However, it has been shown that the typical reverberation time of rooms in dwellings corresponds better with the T_0 than the calculated absorption area with the A_0. Moreover, the measured reverberation times has been shown to be close to 0.5 s (12), also in Finnish dwellings (11).

Until 1967, Finland preferred the standardized SNQ $L'_{nT,w}$ as the measure for impact sound insulation between dwellings. After that, Finland has defined the requirements as a normalized SNQ $L'_{n,w}$. (13) Part of this preference of normalization method was because of the criticism in 1965 against standardization of measured impact sound pressure levels (14).

At the moment, the number of European countries that apply SNQs $L'_{n,w}$, $L'_{n,w} + C_{I,50\text{-}2500}$, $L'_{nT,w}$ and $L'_{nT,w} + C_I$ for regulatory requirements is 18, 1, 8 and 2 countries, respectively. None of the European countries that participated in the COST Action TU0901 used $L'_{n,w} + C_I$ or $L'_{nT,w} + C_{I,50\text{-}2500}$ as a descriptor for the impact sound insulation requirements. In the final report of the work of the COST Action, it has been proposed that both $L'_{nT,w}$ and $L'_{nT,w} + C_{I,50\text{-}2500}$ should be used as the SNQ for impact sound insulation between dwellings. (15) The use of the standardization instead of normalization has also been proposed in earlier studies (e.g. 16, 17).

It has been proposed that the R'_w should be replaced with the $D_{nT,w}$ as the primary SNQ for rating the airborne sound insulation of dwellings (11, 15, 18, 19). It has also been shown that the $D_{nT,w}$ corresponds better with the transmitted living sounds than the R'_w (11). However, it seems obvious that there is no research showing which SNQ used for rating the impact sound insulation between dwellings corresponds best with transmitted impact sound pressure levels.

1.2 Objectives

The object of this paper is to study which SNQ corresponds best with transmitted impact sound pressure levels in buildings. The method of this study is to use existing Finnish field measurement data (20) for calculating the SNQs for impact sound insulation and the transmitted sound pressure levels generated by the tapping machine. A correlation analysis between the SNQs and the transmitted impact sounds is carried out.

2. MATERIALS AND METHODS

2.1 Field measurements of impact sound insulation

In this study, Finnish database including field measurements is used in order to calculate SNQs and transmitted impact sound pressure levels generated by the tapping machine. The data has been published in ref. (20). The measurements had been done in Finland as a part of ordinary consultancy during years 2009–2013 according to the standard ISO 140-7 (21). All the measurements were carried out in furnished rooms in apartment buildings constructed between 1885 and 2013. Both horizontal and vertical measurement directions were included in the database.

The collected database includes information of the floor construction, volume of source and receiving rooms as well as reverberation times, background noise levels and impact sound pressure levels L_2 measured in the receiving room. All sound pressure levels and reverberation times were measured at 1/3-octavebands in the frequency range 50–5000 Hz.

Impact sound insulation data was collected from 110 field measurements. The database included measurements carried out on 26 lightweight, 49 concrete, 19 mixed lightweight and concrete and 16 other floor structures. The receiving room volumes varied from 18 m^3 to 301 m^3 (see Figure 1). The normalized impact sound pressure levels L'_n and standardized impact sound pressure levels L'_{nT} were

calculated on the basis of the collected database according to the standard ISO 140-7 (21). Percentiles and mean values of measured impact sound pressure levels L'_n and L'_{nT} have been shown in Figure 2 at the 1/3-octavebands.

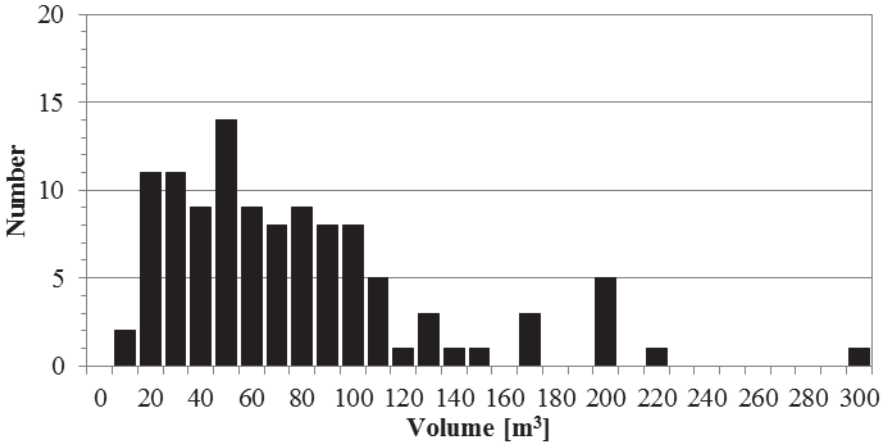

Figure 1 – Distribution of the volumes V of the receiving rooms

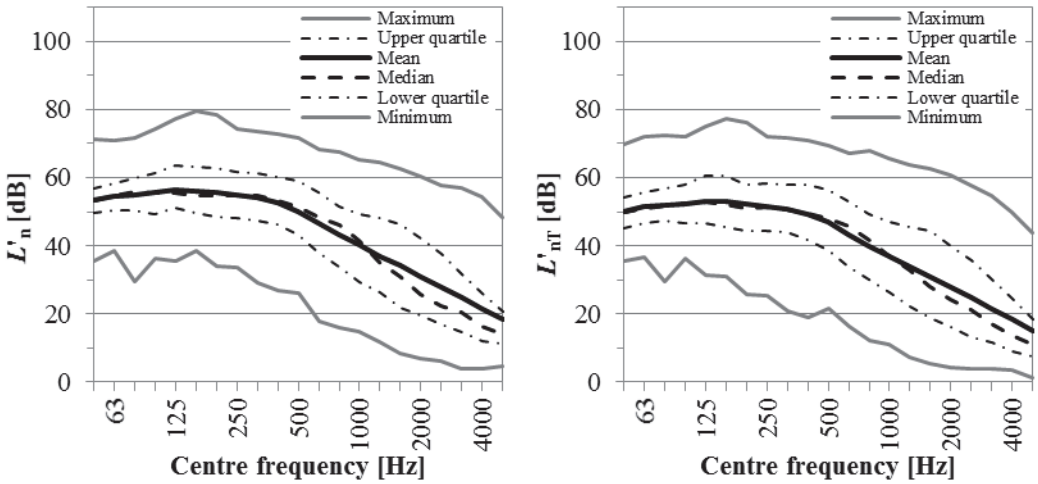

Figure 2 – Percentiles and mean values of the 110 measured normalized and standardized impact sound pressure levels L'_n and L'_{nT}

2.2 SNQs and transmitted tapping machine levels for rating of impact sound insulation

The values of normalized SNQs $L'_{n,w}$, $L'_{n,w} + C_I$ and $L'_{n,w} + C_{I,50\text{-}2500}$ and standardized values $L'_{nT,w}$, $L'_{nT,w} + C_I$ and $L'_{nT,w} + C_{I,50\text{-}2500}$ were calculated on the basis of the field measurements. The calculation of the SNQs was made according to the newest revision of the standard ISO 717-2 (22) although the measurements were made before the release of the standard. The newest revision of the standard was used because it allows moving the reference curve in 0.1 dB steps and thus enables more precise evaluation of the correlation between the SNQs and the transmitted impact sound pressure levels. In the Figure 3 the distribution of the values of different SNQs has been shown. The ranges of the measured SNQs were:

- $L'_{n,w}$: 31.2 - 69.6 dB
- $L'_{n,w} + C_I$: 33.3 - 70.2 dB
- $L'_{n,w} + C_{I,50\text{-}2500}$: 36.8 - 70.5 dB
- $L'_{nT,w}$: 23.1 - 67.5 dB
- $L'_{nT,w} + C_I$: 25.2 - 68.1 dB
- $L'_{nT,w} + C_{I,50\text{-}2500}$: 37.4 - 68.3 dB

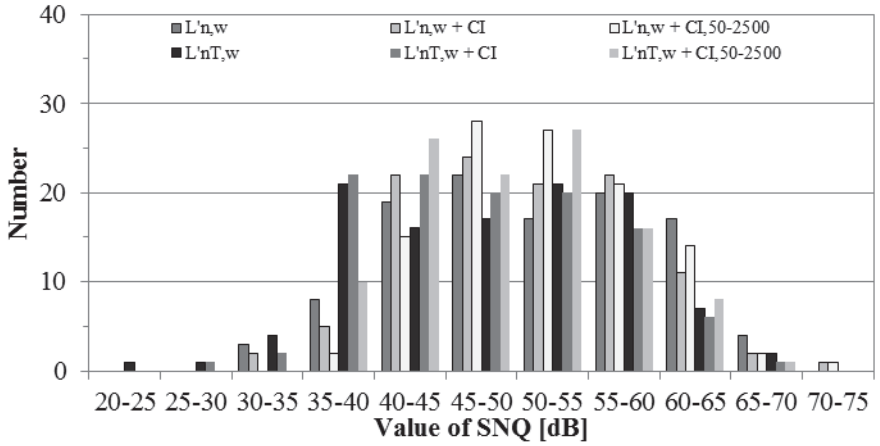

Figure 3 – Distribution of the values of 110 different SNQs in eleven categories

In order to study the correlation between the SNQs and the transmitted impact sound pressure levels, L_{eq} generated by the tapping machine were calculated, too. The impact sound pressure levels $L_{eq,2}$ were calculated from the L_2 spectra in the receiving room on the basis of the field measurements. Thus, the SNQs were compared to the objective impact sound pressure levels on corresponding measurement. The associations between the SNQs and the transmitted sound pressure levels $L_{eq,2}$ generated by the tapping machine were studied by calculating the coefficients of determination R^2.

3. RESULTS

The transmitted sound pressure levels $L_{eq,2}$ as a function of the SNQs of impact sound insulation have been shown in Figure 4. In the figure, the coefficients of determination R^2 have been shown for each SNQ and $L_{eq,2}$ combination, too. The figure includes results for all the rooms studied in this paper.

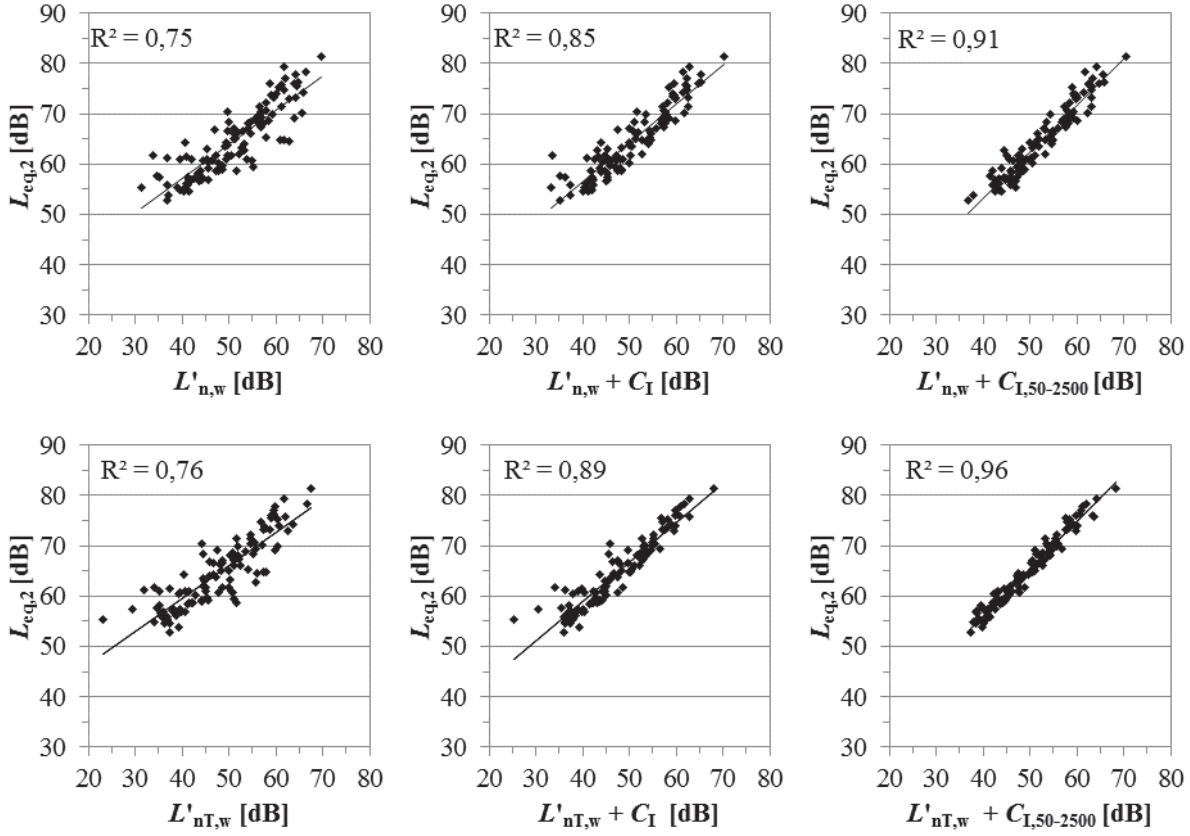

Figure 4 – Transmitted sound pressure levels $L_{eq,2}$ as a function of the SNQs for impact sound insulation

4. CONCLUSIONS

It has long been recognized that the normalized and standardized SNQs rate the impact sound insulation between dwellings differently. However, the difference between the SNQs does not prove which of them describes the transmission of impact sounds between rooms most correctly. In this study, the values of normalized SNQs $L'_{n,w}$, $L'_{n,w} + C_I$ and $L'_{n,w} + C_{I,50\text{-}2500}$ and standardized values $L'_{nT,w}$, $L'_{nT,w} + C_I$ and $L'_{nT,w} + C_{I,50\text{-}2500}$ were calculated on the basis of 110 field measurements. In order to compare the SNQs to the impact sound pressure levels objectively, the transmitted sound pressure levels $L_{eq,2}$ generated by the tapping machine were calculated, too.

The difference between SNQs can also be seen from Figure 3, where the distributions of normalized and standardized SNQs are different. The reason for this is different room volumes. The larger the room volume is, the larger are the normalized SNQs compared to the standardized SNQs. This, however, does not prove which of them is correct and is why a correlation analysis was carried out in this study (see Figure 4).

All correlations were statistically significant. However, all the standardized SNQs lead to higher correlation with $L_{eq,2}$ than corresponding normalized SNQs. The correlation was highest between $L_{eq,2}$ and the standardized SNQ $L'_{nT,w} + C_{I,50\text{-}2500}$. This means that objectively all the standardized SNQs could rate the impact sound insulation between dwellings better than normalized SNQs. It is thus justified to replace $L'_{n,w}$ with $L'_{nT,w}$ as the SNQ for rating the impact sound insulation.

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