Assessment of the low-frequency procedure in the field measurements of impact sound insulation

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Abstract
In 2015, the new standard ISO 16283-2 for field measurements of impact sound insulation introduced a low-frequency procedure (LF-procedure) for measuring impact sound pressure levels and reverberation times at three 1/3-octave bands below 100 Hz. The LF-procedure is followed when the volume of the receiving room is smaller than 25 m^3. The LF-procedure is based on studies concerning field measurements of airborne sound insulation. Its aim is to improve measurement uncertainty of low-frequency sound insulation measurements. The procedure has not been assessed for use with impact sound insulation measurements. The objective of this study was to assess the standardized LF-procedure in the field measurements of impact sound insulation. The results show that the measurement uncertainty is improved. However, the impact sound pressure levels raise 4 dB on average. The values of $L'_{nT,w} + C_{I,50\text{-}2500}$ also raise from 1 dB to 8 dB in most cases.

Keywords: building acoustics, impact sound insulation, low frequencies, measurement uncertainty

1 Introduction

In 2015, the field measurement standard ISO 140-7 [1] of impact sound insulation was replaced by a new standard ISO 16283-2 [2] which introduced a low-frequency procedure (LF-procedure) for measuring impact sound pressure levels and reverberation times at the three 1/3-octave bands below 100 Hz. This new standard has been revised in 2018 and 2020 [3–4]. The LF-procedure is followed when the volume of the receiving room is smaller than 25 m^3. The LF-procedure for measuring the impact sound pressure levels consists of additional sound pressure level measurements in at least four room corners and combining them in a special way with the sound pressure levels acquired with the normal method. The low-frequency energy average is calculated for each of the 1/3-octave bands of 50, 63 and 80 Hz separately. In reverberation time measurements, the low-frequency procedure requires that the reverberation time measured at 63 Hz octave band is used in the calculation of e.g. L'_{nT} instead of the measured reverberation times at 1/3-octave bands 50, 63 and 80 Hz.

The LF-procedure included in the current standard [4] is based on the work carried out by Hopkins and Turner [5]. They studied airborne sound insulation measurements in rooms having a small volume at the low frequency range where diffuse sound field cannot be expected. The developed method is applied in the field measurement standard of airborne sound insulation [6]. The aim of the work by Hopkins and Turner was to improve the repeatability of low frequency sound insulation measurements. Hopkins and Turner did not study the applicability of the developed low frequency measurement method in measuring the impact sound insulation [5].

The objective of this study is to assess the standardized LF-procedure in the field measurements of impact sound insulation. The assessment of the LF-procedure in field measurements of impact sound insulation is carried out in the same way as Hopkins and Turner [5] assessed the LF-procedure in the field measurements of airborne sound insulation. First, the differences between the impact sound pressure levels with and without the LF-procedure defined in the current standard [4] will be calculated. Measurement uncertainty will also be assessed by defining the standard deviations of the measured impact sound pressure levels. Second, the differences between the single-number quantities (SNQ) for rating the impact sound insulation will be determined. This paper is a short version of a larger work presented in [7].

2 Materials and methods

There are several SNQs defined for the rating of impact sound insulation between dwellings, like weighted standardized impact sound pressure level $L'_{nT,w}$ and sum of it and the spectrum adaptation term C_I or $C_{I,50\text{-}2500}$ [8–9]. As many countries use the SNQs standardised to reverberation time, this paper presents results concerning them only. The spectrum adaptation term $C_{I,50\text{-}2500}$ is the only one affected by the LF-procedure. Thus, this paper concerns only the differences of the sum of $L'_{nT,w}$ and $C_{I,50\text{-}2500}$ calculated with and without the LF-procedure.

The measurement data used in this study has been produced as a part of everyday consultation work by the acoustical department of AINS Group. The measurements have been carried out according to the default measurement procedure and LF-procedure. In the default measurement procedure, four tapping machine and four fixed microphone positions per each tapping machine position have been used when measuring the impact sound pressure levels. The data consists of 40 field measurements results in new buildings. The volume of the receiving rooms ranged from 16 m^3 to 24 m^3. Most of the measurement results (35) are from wooden buildings except five which have been done in concrete buildings.

Standardised impact sound pressure levels L'_{nT} from all the measurement results calculated with and without the LF-procedure have been shown in Figure 1. An example of the difference between the measured levels with and without the LF-procedure in one measurement result has also been shown in Figure 1. Differences between the impact sound pressure levels in 1/3-octave bands with and without the LF-procedure have been calculated as follows:

$$D_{nT,LF,k} = L'_{nT,LF,k} - L'_{nT,k} \quad (1)$$

Subscript k refers to the 1/3-octave bands of 50, 63 and 80 Hz. In addition to the differences described above, also the average differences and standard deviations of the differences defined by the formula (1) have been determined.

Reducing the measurement uncertainty has been the main objective of introducing the LF-procedure [5]. Therefore, standard deviations of the impact sound pressure levels before normalization or standardization L'_i calculated with and without the LF-procedure have also been determined to find out how the LF-procedure has affected the spread of the measurement results at the low frequency range. The measurement standard [4] requires that an energy-average is first calculated from the measured and background noise corrected impact sound pressure levels for one tapping machine position. Therefore, the energy-averaged impact sound pressure levels per one tapping machine position are based on sound pressure level measurements at four microphone positions. As there has been four tapping machine positions, the standard deviations can be calculated from the four energy-averaged impact sound pressure levels. These standard deviations have been denoted as s_i for the impact sound pressure levels without the LF-procedure and $s_{i,LF}$ for the impact sound pressure levels with the LF-procedure.

Differences between the SNQs calculated from the field measurement results of impact sound pressure levels with and without the LF-procedure have been calculated as follows:

$$D_{nT,SNQ} = (L'_{nT,w} + C_{I,50\text{-}2500,LF}) - (L'_{nT,w} + C_{I,50\text{-}2500}) \quad (2)$$

For the assessment of the LF-procedure, the averages and standard deviations of the differences $D_{nT,SNQ}$ have also been determined.

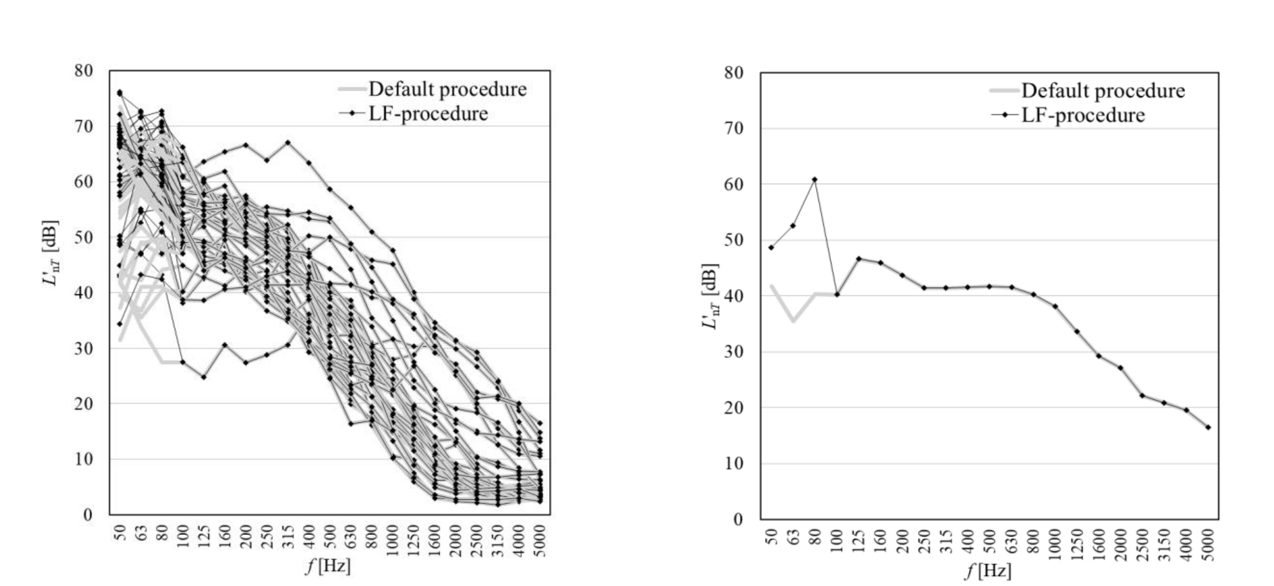

Figure 1 – Measured standardised impact sound pressure levels L'_{nT} with and without LF-procedure in all 40 field measurements (left) and an example from one measurement (right).

3 Results

Averages and standard deviations of $D_{nT,LF,k}$ at 1/3-octave bands of 50, 63 and 80 Hz have been presented in Table 1. Distributions of the differences of $D_{nT,LF,k}$ at the three 1/3-octave bands have been shown in Figure 2. Standard deviations of the energy-averaged impact sound pressure levels defined from the results with LF-procedure and default procedure have been shown in Figure 3. Differences of the single-number quantities $L'_{nT,w} + C_{I,50\text{-}2500}$ calculated with LF-procedure and default procedure have been shown in Figure 4. Average difference is 3,0 dB and standard deviation 2,3 dB.

Table 1 – Averages and standard deviations of differences of impact sound pressure levels measured calculated with and without the LF-procedure.

Difference	Average	Standard deviation
$D_{nT,LF,\ 50\ Hz}$	4,2 dB	2,5 dB
$D_{nT,LF,\ 63\ Hz}$	4,2 dB	3,3 dB
$D_{nT.LF,\ 80\ Hz}$	4,7 dB	4,1 dB

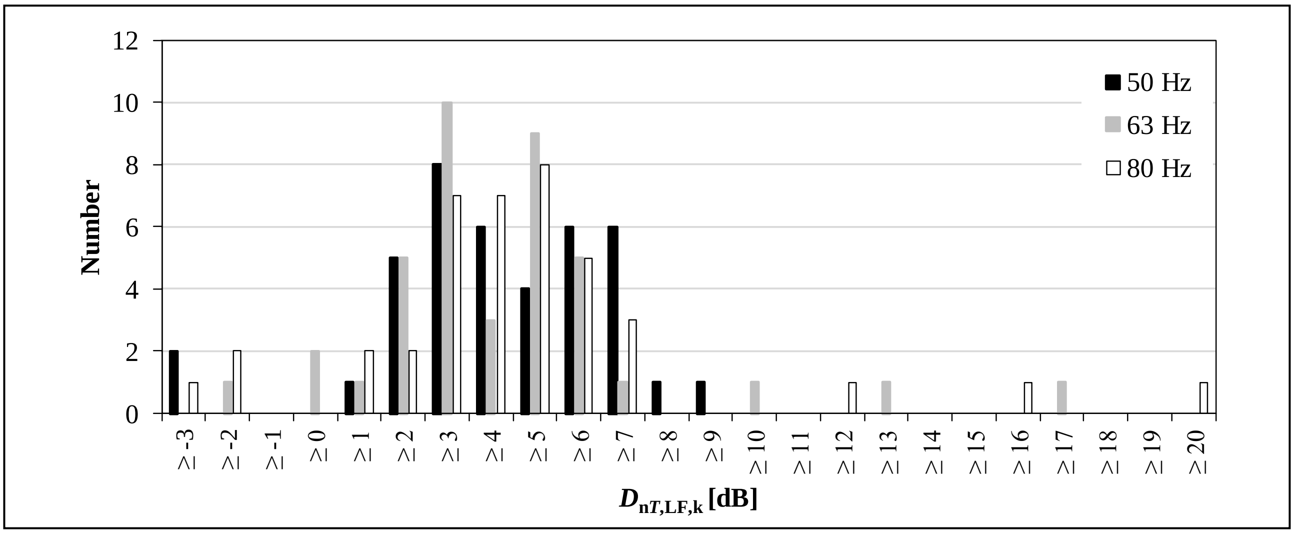

Figure 2 – Distribution of the differences $\underline{D}_{nT,LF,k}$ at 1/3-octave bands of 50, 63 and 80 Hz.

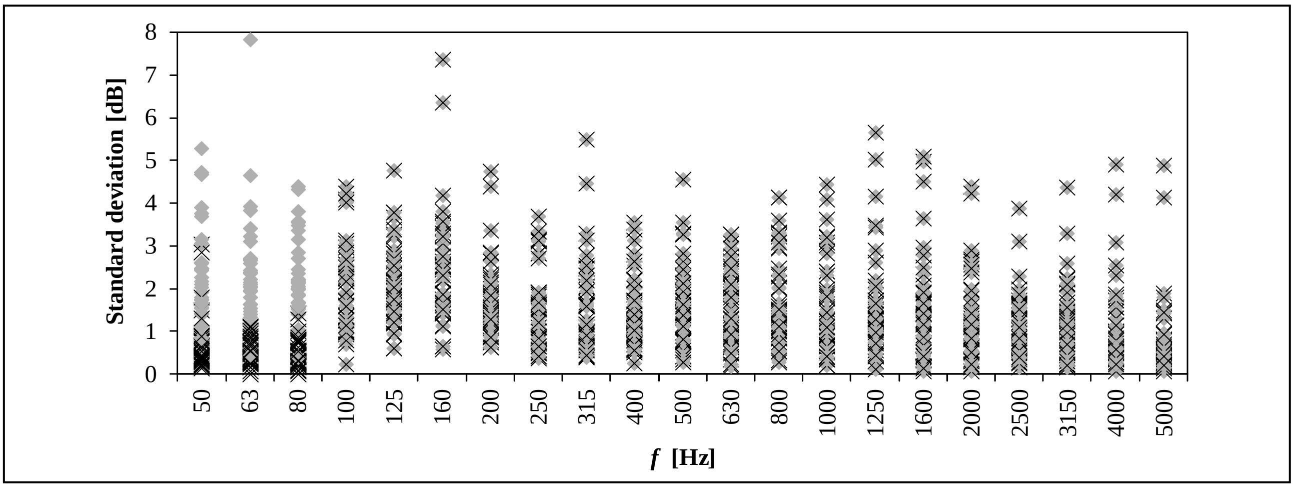

Figure 3 – Standard deviations s_i (default procedure, denoted as ♦) and $s_{i,LF}$ (LF-procedure, denoted as ×) calculated from the four energy-averaged impact sound pressure levels.

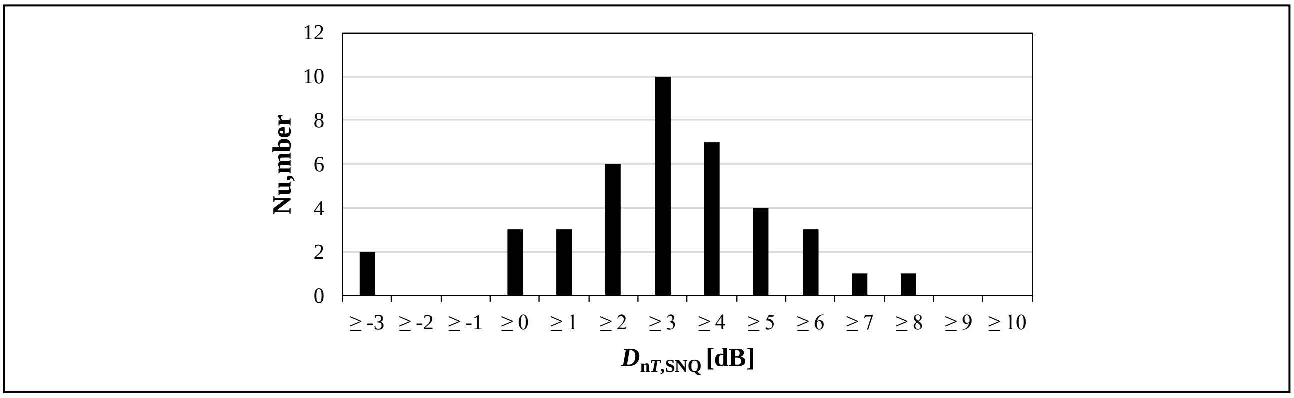

Figure 4 – Distribution of the differences of the single-number quantities $D_{nT,SNQ}$.

4 Discussion

The low-frequency measurement procedure for measurements of both airborne and impact sound insulation was included in the measurement standards [2, 6] in order to improve the repeatability of low frequency sound insulation measurements [5]. The results (Fig. 3) indicate that the LF-procedure works as was expected: the standard deviations of the impact sound pressure levels are low compared with those obtained without LF-procedure. However, the standard deviation of the results obtained without the default procedure within this frequency range do not drastically stand out from the deviation of the adjacent frequency bands from 100 to 200 Hz (Fig. 3). In an earlier study concerning impact sound insulation of concrete floors [10], it was shown that the measurement uncertainty increases just around 0,5 dB at the low frequencies of 50, 63 and 80 Hz compared with the measurement uncertainty at the 1/3-octave bands from 100 to 250 Hz. This raises a question whether there is any need to improve measurement repeatability between 50 and 80 Hz.

The reason for the lower standard deviations of the energy-averaged impact sound pressure levels measured with LF-procedure can be explained by the results shown in Fig. 1 and Fig. 2. In most cases, the impact sound pressure levels having the results from LF-procedure included are clearly larger than the levels without the LF-procedure (Fig. 1). When the same data is studied in terms of standard deviations (Fig 3), the standard deviations from energy-averaged impact sound pressure levels with LF-procedure are lower, correspondingly. Even though the corner pressure levels are weighted with a factor of 1 and the regular pressure levels with a factor of 2 when combined to LF pressures, the results with LF-procedure are probably dominated by the sound pressure levels measured in the room corners. This might result in lower standard deviations and improving repeatability. This assumption is supported by results from a study concerning low-frequency impact sound insulation with a different sound source [11].

Despite the improvement in measurement uncertainty, the LF-procedure might nevertheless lead to problems in rating of the impact sound insulation between dwellings. At 50 Hz, the difference $D_{\mathrm{nT,LF,50\ Hz}}$ is above zero in 38 cases of 40 field measurements. At 63 Hz, one results is below zero and all others are equal to it or larger. At 80 Hz, three results are below zero (Fig. 2). The average differences are from 4,2 dB to 4,7 dB (Table 1). At single field measurement cases, the difference might be even 20 dB at some of the 1/3-frequency bands (Fig. 2). Thus, the LF-procedure seems to lead to much higher impact sound pressure levels than the default procedure.

The difference in the values of the SNQs $L'_{\mathrm{n}T,\mathrm{w}} + C_{\mathrm{I,50\text{-}2500}}$ were equal to or larger than zero in 38 cases of 40 field measurements when the LF-procedure was applied. 77,5 % of the measurement results increased from 2 dB to 7 dB the largest raise being 8 dB. On the average, the raise was 3,0 dB. According to Hopkins and Turner [5], the change of single-number quantities $D_{\mathrm{n}T,\mathrm{w}} + C_{50\text{–}3150}$ and $D_{\mathrm{n}T,\mathrm{w}} + C_{\mathrm{tr},50\text{–}3150}$ for airborne sound insulation was within the range between -1 dB and +1 dB when the LF-procedure was applied as it is presented in the measurement standard [6]. This might be a result of the use of the LF-procedure twice: the corner measurements will usually be done both in the source and receiving room, when the effect of increasing sound pressure levels due to the corner measurements will be diminished. In the calculation of the level differences *D*, the raise in the 1/3-octave band sound pressure levels will probably be subtracted to some extent, when it will not affect the values of the single-number quantities as much as in the impact sound insulation measurements.

It could also be claimed that the use of the LF-procedure results in SNQs that differ from those used as a basis for the limits of impact sound insulation in national requirements. Thus, the SNQs having the results from LF-procedure included, should have different limits. Another important aspect is whether the values of the SNQs calculated following the LF-procedure correlate with the occupants' subjective judging of the impact sound insulation. It is encouraged that this should be studied with psychoacoustical methods which have been applied in a recent study on impact sound insulation [12].

The measurement standard for impact sound insulation requires that the LF-procedure shall be used when the room volume is less than 25 m^3 [4]. In practice, there will occur situations where similar structures in rooms having a volume of slightly smaller or larger than 25 m^3, will lead to greatly different results. Furthermore, this means that the small rooms should be designed and constructed differently from the larger rooms, i.e. with floor structures having better impact sound insulation. This leads to rising building costs.

5 Conclusions

The low-frequency procedure for sound insulation measurements [4, 6] was developed in order to improve the measurement uncertainty. It was studied on the basis of the airborne sound insulation measurements [5]. According to Hopkins and Turner [5], a measurement method for sound insulation should have a suitable repeatability, reproducibility and relevance which they defined as a link between the insulation measured and the insulation experienced by the building occupants. An assessment of the LF-procedure in impact sound insulation measurements has not been carried out earlier. Our study shows that the procedure is successful in improving the measurement uncertainty. However, there are several problems concerning the application of the LF-procedure in field measurements of impact sound insulation. The application of the LF-procedure changes the rating of impact sound insulation in small rooms so much that its use is so far not justified.

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