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ROUND ROBIN TEST ON AIRBORNE SOUND INSULATION IN FINLAND

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ABSTRACT

The Acoustical Committee of the Finnish Association of Civil Engineers RIL organized a round robin test on airborne sound insulation measurements in 2022. The test was participated by 15 measurement groups from 11 organizations and the test was carried out in an office building made of concrete. Airborne sound insulation between two office rooms separated by a plasterboard wall was measured horizontally in accordance with the standard ISO 16283-1 and single-number quantities were calculated according to the standard ISO 717-1. The participants determined independently apparent sound reduction indices R' and standardized level differences D_{nT} at one-third octave bands and calculated single-number quantities R'_w and $D_{nT,w}$ as well as spectrum adaptation terms from their own results. The weighted apparent sound reduction index R'_w was between 43 and 46 dB while the average was 44,5 dB and the standard deviation 0,7 dB. The weighted normalized level difference $D_{nT,w}$ ranged from 43 to 46 dB while the average was 44,8 dB and the standard deviation 0,9 dB. Compared to the standard uncertainties presented in the standard ISO 12999-1, the deviation of the results was larger in the frequency range from 1000 to 2000 Hz and at centre frequencies of 125 and 400 Hz.

Keywords: *airborne sound insulation, building acoustics, measurement uncertainty, sound insulation, round robin*

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1. INTRODUCTION

Round robin tests have been organized in Finland three times by the Acoustical Committee of the Finnish Association of Civil Engineers RIL. The first test concerning measurements of airborne sound insulation in the field was carried out in 2016 [1]. The second test dealing with field measurements of impact sound insulation was done in 2018 [2].

One purpose of the round robin tests organized by the Acoustical Committee of RIL has been to offer an opportunity to compare measurement results and to confirm their validity for operators carrying out sound insulation measurements in Finland. For several participating organizations operating as accredited testing laboratories, the round robin tests have offered valuable comparison data for the accreditation processes. The main object of the tests has been reducing the measurement uncertainty and raising the quality level of measurement activities.

The third round robin test, now concerning field measurements of airborne sound insulation again, was organized by RIL in 2022. In total, 15 measurement results were obtained from the groups from 11 different organizations who measured airborne sound insulation between two adjacent rooms horizontally. The organizations that took part in the measurements were both educational and research institutes, testing laboratories as well as engineering design companies working in the field of acoustical engineering.

The aim of the round robin carried out in 2022 was, in addition to that said above, was to study whether the measurement uncertainty of airborne sound insulation measurements had been decreased and whether the quality level of the measurements had been increased since 2016 when the first round robin on airborne sound insulation was done.

2. METHODS

2.1 Arrangements

The Acoustical Committee of RIL sent a letter of invitation to the round robin test to Finnish organizations carrying out field measurements in April 2022. In May 2022, a more specific information letter was sent to those registered for the test. The measurements were done in an office building made of cast concrete. The building located in Tampere, Finland was finished in 1974 and renovated in 2017 (Fig. 1). The spaces for the test were provided by AINS Group.

The participants were informed that the measurements will be done horizontally between two small adjacent meeting rooms (Fig. 2). Furthermore, the participants were told that the separating wall between the meeting rooms is a light-weight wall and that the airborne sound insulation between the rooms was estimated to be 40–50 dB expressed as weighted standardized level difference $D_{nT,w}$.

Figure 1. The office building where the round robin test was carried out. Source: Archives of AINS Group.

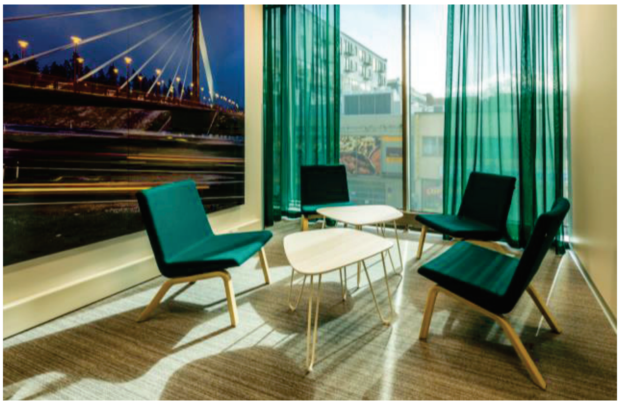

Figure 2. Meeting room where the measurements were carried out. Source: Archives of AINS Group.

2.2 Measurements

The participants were directed to carry out the measurements in accordance with the valid standard ISO 16283-1 [3] and determine the single-number quantities for rating the airborne sound insulation according to the standard ISO 717-1 [4] and by using their respective measuring devices. Each of the participants had to carry out the measurements and to determine the room dimensions and the measurement conditions independently.

The participants determined apparent sound reduction indices R' and standardized level differences D_{nT} in 1/3-octave-bands from their measurements. From these results, the groups calculated the corresponding single-number quantities (SNQ's) R'_w and $D_{nT,w}$, as well as spectrum adaptation terms C, C_{tr}, $C_{50\text{-}3150}$, $C_{50\text{-}5000}$, $C_{100\text{-}5000}$, $C_{tr,50\text{-}3150}$, $C_{tr,50\text{-}5000}$ and $C_{tr,100\text{-}5000}$ (later, the spectrum adaptation terms in general are denoted as C_i).

2.3 Processing of the results

The participants wrote down their results into a predetermined file, which was sent to the office of RIL. The personnel of RIL anonymized the results before handing them over to the authors. The information connecting the measurement result and the measuring organization is only held by RIL. The measurement groups were labelled as 01...15.

The round robin test was reported by the researchers at the Faculty of the Built Environment of Tampere University which did not participate the test. The building acoustics research group determined the averages and standard deviations of the reported airborne sound insulation values both at 1/3-octave bands and of the single-number quantities.

3. RESULTS

3.1 Measured sound insulation values

All results of the apparent sound level indices R' and the standardized level differences D_{nT} are shown in 1/3-octave-bands in Figures 3 and 4. The standard deviation of all the apparent sound level indices R' was 0,7–3,0 dB. The standard deviation of the standardized level differences D_{nT} was 0,7–2,9 dB. The determined volume of the receiving room varied from 44,8 to 48,0 m^3 except in one case where the determined volume was 63,1 m^3 which can be interpreted as an outlier.

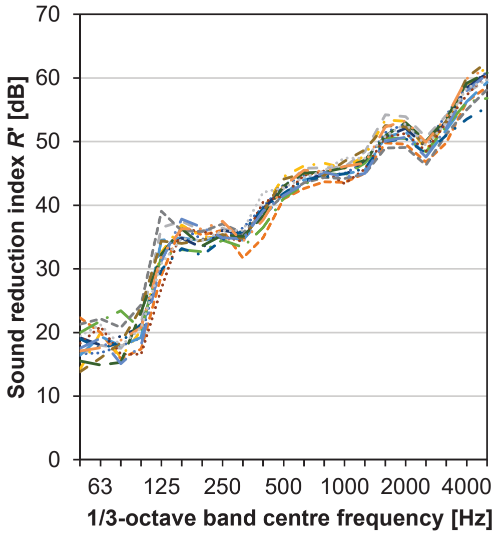

Figure 3. The measured apparent sound reduction indices R' reported by the 15 measurement groups.

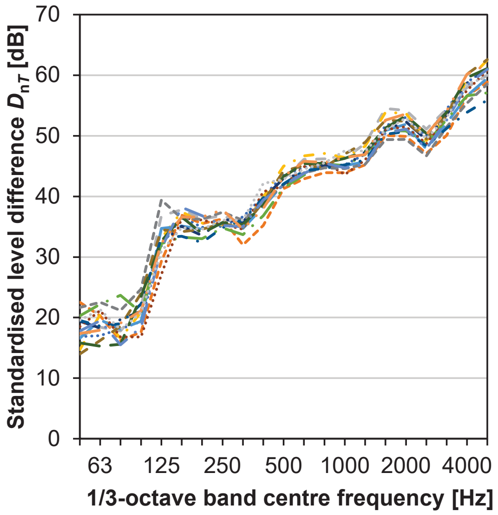

Figure 4. The measured standardized level differences D_{nT} reported by the 15 measurement groups.

3.2 Single-number quantities

Tables 1 and 2 show averages, minimum and maximum values, as well as standard deviations of the SNQ's R'_w, $R'_w + C_i$, $D_{nT,w}$ and $D_{nT,w} + C_i$. None of the results were excluded even though there was an outlier concerning the determination of the receiving room volume. This group reported also a larger area for the separating wall which compensated the erroneous room volume. Thus, the calculated R' results did not differ from other groups' results.

Based on all results, the average of the SNQ R'_w was 44,5 dB and the standard deviation 0,7 dB. The corresponding results for the SNQ $D_{nT,w}$ were 44,8 dB and 0,9 dB.

Table 1. Averages (AVG), minimum (MIN) and maximum (MAX) values, as well as standard deviation (STD) of the SNQ's R'_w and $R'_w + C_i$.

SNQ	AVQ	MIN	MAX	STD
R'_w	44,5	43	46	0,7
$R'_w + C$	42,9	41	44	1,0
$R'_w + C_{tr}$	37,7	35	40	1,6
$R'_w + C_{50\text{-}3150}$	41,9	40	43	0,8
$R'_w + C_{50\text{-}5000}$	42,9	41	44	0,8
$R'_w + C_{100\text{-}5000}$	43,8	42	45	1,0
$R'_w + C_{tr,50\text{-}3150}$	33,5	32	37	1,3
$R'_w + C_{tr,50\text{-}5000}$	33,5	32	37	1,3
$R'_w + C_{tr,100\text{-}5000}$	37,7	35	40	1,6

Table 2. Averages, minimum and maximum values, as well as standard deviation of the SNQ's $D'_{nT,w}$ and $D'_{nT,w} + C_i$.

SNQ	AVQ	MIN	MAX	STD
$D'_{nT,w}$	44,8	43	46	0,9
$D'_{nT,w} + C$	43,1	41	44	1,0
$D'_{nT,w} + C_{tr}$	38,1	35	40	1,5
$D'_{nT,w} + C_{50\text{-}3150}$	42,2	40	43	1,0
$D'_{nT,w} + C_{50\text{-}5000}$	43,1	41	44	0,9
$D'_{nT,w} + C_{100\text{-}5000}$	44,1	42	45	1,0
$D'_{nT,w} + C_{tr,50\text{-}3150}$	34,0	33	37	1,2
$D'_{nT,w} + C_{tr,50\text{-}5000}$	34,0	33	37	1,2
$D'_{nT,w} + C_{tr,100\text{-}5000}$	38,1	35	40	1,5

3.3 Measurement uncertainties

According to the standard ISO 12999-1 [5], the standard deviation of the measurement results can be used for determining the uncertainty of the measurement results. Since all the participants carried out their measurements independently at the same location using their own equipment, the test corresponded the measurement situation B of the standard. Figures 5 and 6 show the standard deviation of the apparent sound reduction indices R' and the standardized level differences D_{nT} (N = 15).

The figures 5 and 6 also show the standard uncertainty of the situation B presented in the standard. Tables 3 and 4 show the standard deviations of the results of the SNQ's and the standard uncertainties for single-number values presented in the standard.

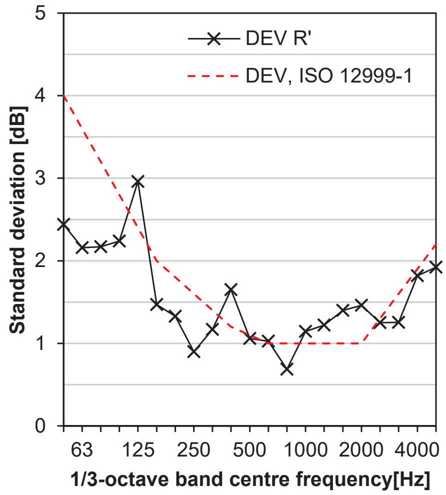

Figure 5. The standard deviations (DEV) of the apparent sound level indices *R'* (N = 15). The standard uncertainty is presented as a red dashed line.

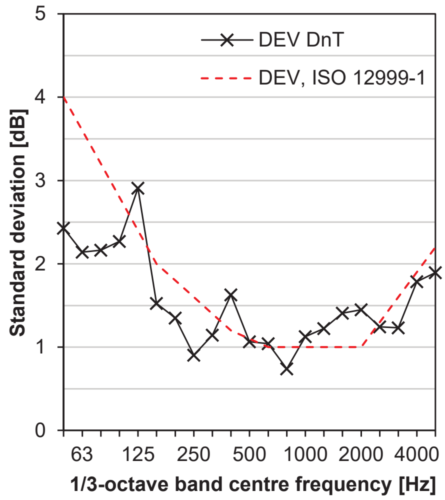

Figure 6. The standard deviations (DEV) of the standardized level differences D_{nT} (N = 15). The standard uncertainty is presented as a red dashed line.

4. DISCUSSION

4.1 Standard deviation of the SNQs

The standard deviations of the SNQ's R'_w and $D_{nT,w}$ were roughly the same, 0,7 and 0,9 dB, respectively. The standard deviations of the sums of the SNQ $D_{nT,w}$ and the spectrum adaptation terms $C_{50\text{-}3150}$, $C_{50\text{-}5000}$, $C_{tr,50\text{-}3150}$, $C_{tr,50\text{-}5000}$ and $C_{tr,100\text{-}5000}$ were mainly a bit lower than the standard deviations of the sums of the SNQ R'_w and the corresponding spectrum adaptation terms. The differences, however, were very small.

The deviation did not change notably, when the frequency bands from 50 to 100 Hz were taken into account by the spectrum adaptation terms. This was different from the results reported on the basis of the previous round robin test in 2016 [1]. Unlike in the previous round robin, enlarging the frequency range up to 5000 Hz [1] did not result in a change in the deviation.

Table 3. The standard deviation of the apparent sound reduction indices compared with the standard deviation presented in the standard ISO 12999-1 [5].

SNQ	STD	ISO 12999-1
R'_w	0,7	0,9
$R'_w + C$	1,0	0,9
$R'_w + C_{tr}$	1,6	1,1
$R'_w + C_{50\text{-}3150}$	0,8	1,0
$R'_w + C_{50\text{-}5000}$	0,8	1,1
$R'_w + C_{100\text{-}5000}$	1,0	1,1
$R'_w + C_{tr,50\text{-}3150}$	1,3	1,3
$R'_w + C_{tr,50\text{-}5000}$	1,3	1,0
$R'_w + C_{tr,100\text{-}5000}$	1,6	1,1

Table 4. The standard deviation of the standardized level differences compared with the standard deviation presented in the standard ISO 12999-1 [5].

SNQ	STD	ISO 12999-1
$D'_{nT,w}$	0,9	0,9
$D'_{nT,w} + C$	1,0	0,9
$D'_{nT,w} + C_{tr}$	1,5	1,1
$D'_{nT,w} + C_{50\text{-}3150}$	1,0	1,0
$D'_{nT,w} + C_{50\text{-}5000}$	0,9	1,1
$D'_{nT,w} + C_{100\text{-}5000}$	1,0	1,1
$D'_{nT,w} + C_{tr,50\text{-}3150}$	1,2	1,3
$D'_{nT,w} + C_{tr,50\text{-}5000}$	1,2	1,0
$D'_{nT,w} + C_{tr,100\text{-}5000}$	1,5	1,1

4.2 Measurement uncertainty

From Figures 5 and 6, it can be seen, that the standard deviation exceeded the standard uncertainty presented in the standard ISO 12999-1 [5] at frequency bands of 125 Hz, 400 Hz and from 1000 to 2000 Hz. The standard deviation exceeding the allowable value can be explained by Fig. 7 presenting the measured reverberation times. It can be seen that there is probably a room mode at 125 Hz. At 400 Hz, the larger deviation is caused by one measurement result of sound pressure levels that differs from other results (see Fig. 3 and Fig. 4) that differs In the frequency range from 1000 to 2000 Hz, the reasons for the deviation exceeding the allowable values are probably two shorter measurement results of reverberation times at that frequency range (Fig. 7). Based on the data available, the reasons explaining the shorter reverberation times cannot be found afterwards.

From the results presented in the Tables 3 and 4, it can be seen that the standard deviation of SNQ's R'_{w} and $D_{nT,w}$ fulfilled the requirements of the standard ISO 12999-1 [5], but most of the results concerning other SNQs exceeded the allowable deviation. However, the results were maximally 0,5 dB over the allowable values.

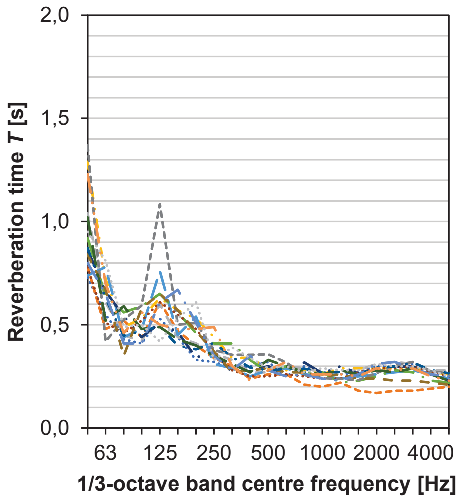

Figure 7. Measured reverberation times by the 15 participating groups.

4.3 Comparison with the previous round robin test

In the previous round robin test in 2016, there were two clear outliers among the 19 results reported by the participants [1]. This time, such clear outliers were not noticed even though the dimensions of the room were determined incorrectly by one measurement group.

The measured situation was different in 2016 as the measurements were carried out in the vertical direction and the averages of R'_{w} and $D_{nT,w}$ were 60,0 dB and 59,2 dB when the outliers were excluded. This time, the averages were 44,5 dB and 44,8 dB, respectively. Thus, the airborne sound insulation in this round robin was around 15 dB lower. This might partly explain the smaller deviation of the measured sound insulation values at high frequency bands.

In general, in this round robin, the standard deviations of the 1/3-octave band results were closer to the allowable values at low frequency range than they were in 2016. In the previous round robin test, the standard deviation was nearly four decibels over the allowable values at the lowest frequency band of 50 Hz. Now, the standard deviation exceeded the limiting values by 0,5 dB at highest.

In the previous tests, no standard deviation of the measured SNQs did not fulfill the allowable limits given in ISO 12999-1 [5]. The results were nearly 3 dB over the allowable values at highest. In this test, the results were maximally 0,5 dB over the limits.

5. CONCLUSIONS

Compared with the previous Finnish round robin test on field measurements of airborne sound insulation in 2016, the measurement uncertainty had decreased. This concerns both the airborne sound insulation values at 1/3-octave bands and single-number quantities. Organizing round robin tests between organizations making field measurements has proven to be valuable. The results show that the quality of airborne sound insulation measurements has improved.

6. ACKNOWLEDGMENTS

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