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Round Robin Test on Building Acoustics with High Sound Insulation

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ABSTRACT

In Austria the standard for classifying sound insulation is ÖNORM B 8115-5. The building legislation regulates the minimum standard only by single number values in the standard frequency range without using spectrum adaption terms. The higher sound insulation classes have significantly higher requirements for airborne and impact sound and this formulated in combination with spectrum adaptation terms including the extended frequency range. It seems to be necessary to explore the uncertainties of sound measurements in this context. This was done in an in situ round robin test conducted in 2018, in which 20 laboratories participated. The measuring objects were chosen in a music school during summer holidays. The sound insulation between the measurement rooms is rather high because of the purpose for music exercise. The measurements had to be carried out according to EN ISO 16283-1 and -2. The challeng due to the high sound insulation was the influence of the external noise and the uncertainty of the low frequencies. Planning, implementation and evaluation of the round robin test were carried out according to the ISO 5725 series. The results are presented and discussed by their causes and consequences.

Keywords: building acoustics, uncertainties, interlaboratory experiment,
I-INCE Classification of Subject Number: 77

1. INTRODUCTION

Already in 1995 [1], the confidence intervals for the details in the building acoustics were determined in round robin tests in Austria. In a further round robin test 2001 [2] for building acoustics measurements the extended frequency range was sampled and confidence intervals were determined. Meanwhile, international and Austrian standardization has already faced the problem of low frequencies in building acoustics. These measurement situations were specified in particular in ÖNORM EN ISO 16283-1 [3] and ÖNORM EN ISO 16283-2 [4].

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In the course of testing laboratories certification it is necessary to be able to demonstrate participation in interlaboratory comparisons. The ÖAL offers these Austrian testing laboratories the opportunity to prove their quality management. This opportunity was taken by a total of 20 Austrian laboratories which provided results on the interlaboratory comparison.

2. METHODS

2.1 Conceptual Formulation

The task was given by measurements of airborne and impact sound insulation according to ÖNORM EN ISO 16283-1 [3] and 16283-2 [4] in horizontal and vertical direction in the music school of Steyregg in Upper Austria. Two directions vertical and horizontal had to be analyzed, each by airborne and impact sound.
The measurement data was entered in specially designed reference sheets by the participants and returned by e-mail to the executive officer. As part of the data collection, the participants were asked to enter the method used in separate sheets for airborne and impact sound as well as for the reverberation time. Various options were requested. Users may choose different measuring methods for airborne and impact sound like listed below

- One- or two-channel airborne sound measurement
- Source spectrum for airborne sound (pink or white)
- Type of microphone positioning
    - fixed on tripod,
    - moved mechanical or
    - moved manually;
- Determination of the reverberation time
    - procedure of the interrupted noise method or
    - the integrated impulse response method,
- Person presence in the source and in the receiving room.

2.2 Description of the Rooms

The rooms and separating elements are described in table 1.

Table 1: description and size of the rooms and separating elements

function	**description**	**area [m²]**	**volume [m³]**
source room	piano exercise room	26	74
receiving room horizontal	classroom	21	59
receiving room vertical	conference room	28	79
separating element horizontal	lightweight gypsum	15	-
separating element vertical	reinforced-concrete floor with additional gypsum ceiling	26	-

Figure 1 gives an overview of the transmission situation for the different measurement tasks.

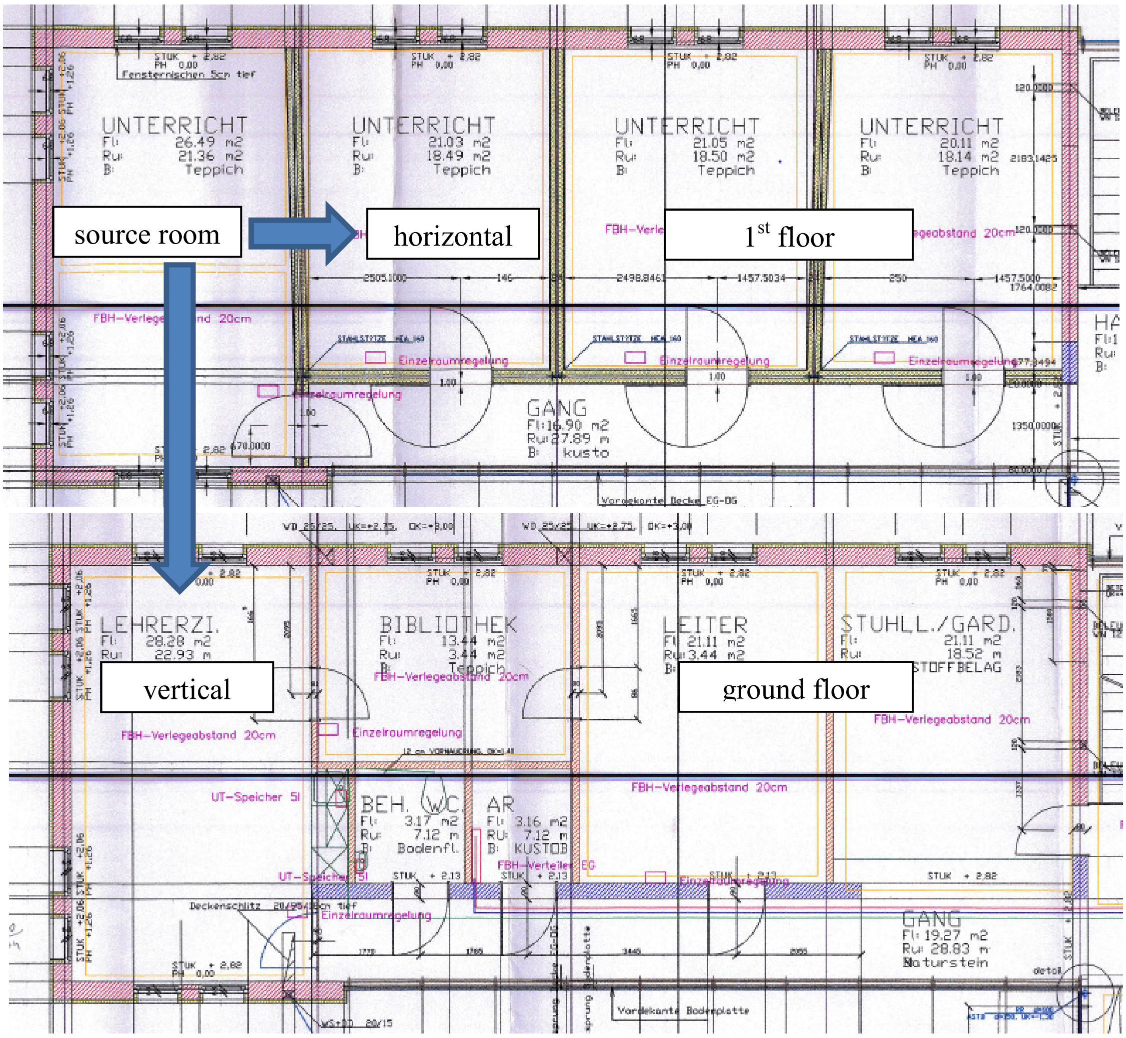

Figure 1: sound transmission situation for measurement tasks

The Means of single number quantities of all measurements (5 per laboratory) of the 20 laboratories are shown in table 2.

Table 2: Means of single number quantities in dB

airborne sound insulation			**impact sound insulation**		
	vertical	**horizontal**		**vertical**	**horizontal**
$D_{nT,w}$	65,0	62,4	$L'_{nT,w}$	36,8	34,6
C	–2,2	–4,1	C_I	–4,6	–2,0
C_{tr}	–5,9	–11,1	$C_{I,\ 50\text{-}2500}$	8,3	2,3
$C_{50\text{-}3150}$	–3,8	–7,3	–	–	–
$C_{50\text{-}5000}$	–2,8	–6,4	–	–	–
$C_{100\text{-}5000}$	–1,4	–3,2	–	–	–
$C_{tr,50\text{-}3150}$	–12,9	–18,5	–	–	–
$C_{tr,50\text{-}5000}$	–12,9	–18,5	–	–	–
$C_{tr,100\text{-}5000}$	–6,0	–11,1	–	–	–

The receiving room vertical is a fully furnished conference room with a large conference table in the middle of the room. Additional dampening with room acoustic measures on ceiling or walls was not set in this room. In the receiving room horizontal, the classroom, sound-absorbing materials (acoustic elements) were attached to the ceiling and walls. In both rooms was sufficient furnishing providing a diffuse sound field.

3.1 Statistical Calculations

The interlaboratory test was prepared and evaluated in accordance with ÖNORM EN ISO 12999-1 [5]. The determination of the repeatability and comparison precision was carried out in accordance with ISO 5725-1 [6]. The treatment of statistical outliers was carried out according to DIN ISO 5725-2 [7].

The number n of test results in each laboratory should be chosen so that $p\ (n - 1) \geq 35$, where p is the number of laboratories. Because all 20 laboratories did 5 measurements of each task the requirement according ÖNORM EN ISO 12999-1 [5] is fulfilled: $p\ (n - 1) = 20\ (5 - 1) = 80 \geq 35$.

Mean values and standard deviations of all individual measured values were calculated and are shown in box plots. From the mean values of the standard deviations, the laboratory-internal variance and hence the repeatability limit r were calculated for each laboratory. The variance between the participating laboratories was calculated from the mean values of all individual measurement results and the mean value of the in-house variance. From the variance between the laboratories, the reproducibility limit R is derived.

By means of statistical tests (Grubb´s and Cochran´s test), potential outliers were identified and marked as conspicuous. However, these data was not automatically selected, but subjected to a plausibility check. It turned out that the rounding determinations (indication of the final results rounded to the nearest decibels) meant that such statistical outliers were in most cases no real outliers and could continue to be used.

The method comparison was done by single number quantities according ÖNORM EN ISO 717-1 [8] and ÖNORM EN ISO 717-2 [9] for the airborne and the impact sound $D_{nT,w}$ and $L'_{nT,w}$ for both transmission situation vertically ("ceiling") and horizontally ("wall"). For the influence in the low-frequency range only the most sensitive adaptation terms were used, for airborne sound $C_{tr,50\text{-}5000}$ and for impact sound $C_{I,50\text{-}3150}$. Statistical tests were Mann-Whitney-U-test (in case of two methods), Kruskal-Wallis-test (for microphone positions) and for group comparisons Chi²-test. The level of significance was set at 0.05.

3. RESULTS

3.1 Standard uncertainties and confidence intervals

One main outcome of an interlaboratory experiment is the estimation of the confidence interval. If a single laboratory performs only a single determination γ of the quantity to be measured, the confidence interval for the true value μ (for example, a requirement or a value specified in a contract) is defined due to equation 1:

$$\left(\gamma - \frac{R}{\sqrt{2}}\right) < \mu < \left(\gamma + \frac{R}{\sqrt{2}}\right) \quad (1)$$

In addition to the repeatability limit r and reproducibility limit R also confidence interval is given for each single number quantity in each measurement task.

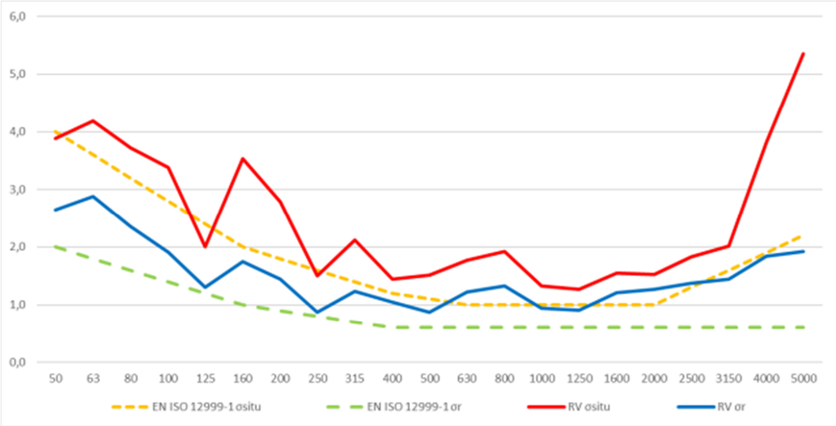

Figure 1: Ceiling vertical: airborne sound insulation– comparison of standard uncertainties with EN ISO 12999-1

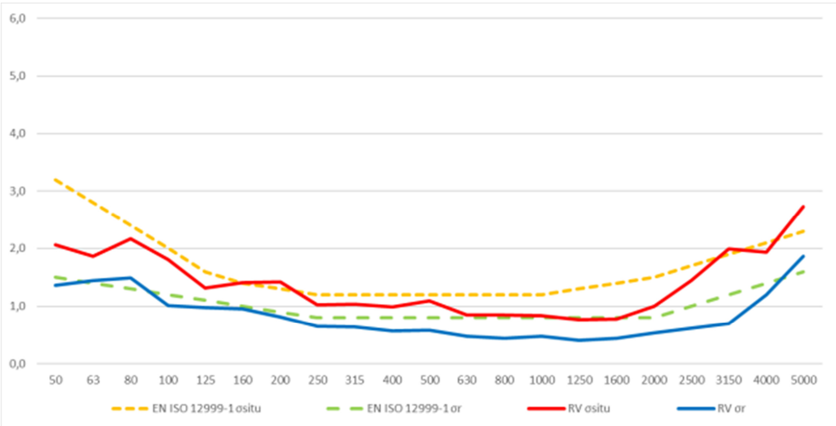

Figure 2: Ceiling vertical: impact sound insulation– comparison of standard uncertainties with EN ISO 12999-1

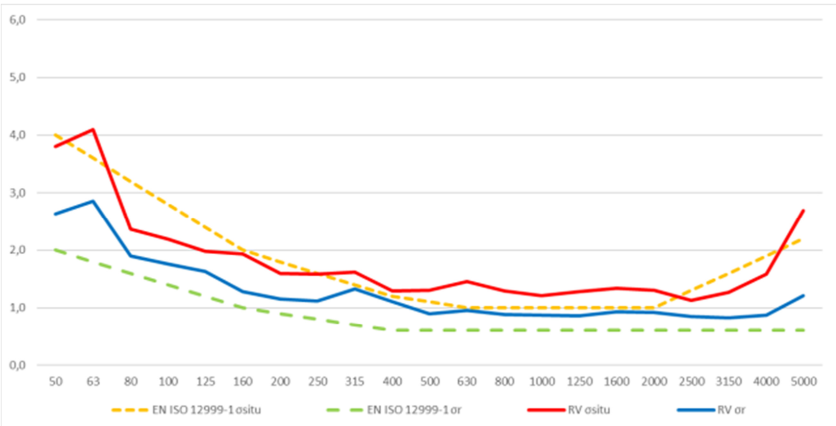

Figure 3: Wall horizontal: vertical airborne sound insulation– comparison of standard uncertainties with EN ISO 12999-1

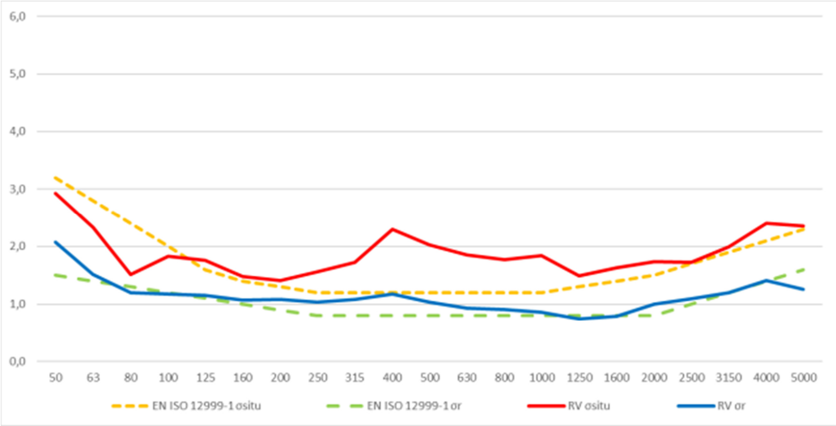

Figure 4: Wall horizontal: vertical impact sound insulation– comparison of standard uncertainties with EN ISO 12999-1

A summary of the confidence intervals for the single number quantities is shown in table 3.

Table 3: summary of the confidence intervals for the single number quantities

airborne sound measurement			impact sound measurement		
	vertical	**horizontal**		**vertical**	**horizontal**
$D_{nT,w}$	2,23	1,82	$L'_{nT,w}$	2,52	1,43
C	1,29	1,89	C_I	0,81	1,40
C_{tr}	1,83	2,90	$C_{I,50\text{-}2500}$	2,93	4,76
$C_{50\text{-}3150}$	1,86	2,42	–	–	–
$C_{50\text{-}5000}$	1,90	2,42	–	–	–
$C_{100\text{-}5000}$	1,46	1,86	–	–	–
$C_{tr,50\text{-}3150}$	4,50	3,99	–	–	–
$C_{tr,50\text{-}5000}$	4,50	3,99	–	–	–
$C_{tr,100\text{-}5000}$	1,86	2,90	–	–	–

3.2 comparisons of measurement methods

For airborne sound measurements the influence of one- or two-channel setup and the influence of the noise spectrum in the source room were checked. 10 laboratories used two channel, the other 10 one-channel setup, 4 used white and 16 used pink noise as spectrum. In no case the level of significance set at 0.05 was achieved. This means that neither the question of one or two-channel measurement nor the use of the frequency spectrum have a significant influence.

Of the 20 laboratories 7 used fixed microphone positions with tripod, 7 test points moved the microphone manually and 6 used a continuously mechanically moved microphone. The p-values are consistently outside the specified significance level. There was no significant influence of the type of microphone positions.

The average duration of the measurements was divided into three groups. If the measurement is a maximum of 15 seconds, it is called short. Measurements longer than 60 seconds are defined as long, measuring times over 15 seconds and less than 60 seconds are classified as medium-length measurement time. In airborne sound

measurement, 7 laboratories were grouped as short, 7 as medium and 6 as long. In the impact sound measurement, 9 were classified as short, 8 as medium and 3 as long.
Table 4 below shows the p-values of the mean comparisons for the airborne and impact sound measurements according to the groups for short, medium and long measurement periods.

Table 4 comparison of the means as p-value according measurement duration

parameter	**airborne sound**		**impact sound**	
	$D_{nT,w}$	$C_{tr,50\text{-}5000}$	$L'_{nT,w}$	$C_{I,50\text{-}2500}$
ceiling vertical	0,053	0,698	0,027	0,232
wall horizontal	0,557	0,821	0,067	0,249

The comparisons of the p-values show asignificant correlation for ceiling measurements of airborne sound and definitely for impact sound. The further evaluation shows the following tendency: The longer the measurement duration, the lower the airborne single-number indication. For impact sound, there is no direction in this context. The most probable reason is the influence of external noise, which is more difficult to control for longer measurements than for short-term measurements, provided that the person measuring is in the room. A general recommendation on the choice of measurement duration cannot be derived from these results.
In 6 airborne noise measurements the reception room was empty and in 14 measurements a person was present. In the source room, the situation was 11 times empty and 9 times a person was present. Using impact sound the receiver room was empty in 6 cases and 14 times a person was present. In no case a significant influence on the fact whether a person is present in the transmission or reception room during the measurement was found.
Of the 20 participating laboratories, 13 used the interrupted noise method, 7 the integrated impulse response method. In summary the evaluation shows that the influence of the reverberation time measurement method is not significant for the single number quantities.

4. CONCLUSIONS

The confidence intervals for der single number quantities in the extended frequency range are very high because of the high sound insulation of the multi-layer constructions. The values for air and impact sound are in an order of 4 dB to 5 dB. By considering the deviations in both directions an effective formulation of requirements is difficult. However in the extended frequency range it would be necessary to combine the requirements for the single number quantities with uncertainty information.

Giving the focus on the comparison of single-number quantities $D_{nT,w}$ and $L'_{nT,w}$, which are currently exclusively binding in nature, the confidence intervals have not changed essentially since the last round robin test. This result was not expected due to the extraordinarily high sound insulation in this interlaboratory comparison. It shows that a high sound insulation level can also be tested with good reproducibility. If the high standard of sound insulation is defined by the extended frequency range, this statement cannot be maintained.
In this interlaboratory comparison, the effects of different measurement methods on the mean values of the single numbers quantities and of the spectrum adaptation terms in

the extended frequency range were also performed as highly sensitive indices. It turns out that there are no statistically significant correlations to the values due to single or multi-channel measurement, by selecting the transmission spectrum, microphone positions, type of reverberation time measurement and presence of persons in transmission and reception rooms. Only the duration of the measurement has a slight influence on the airborne sound measurement, which might be due to the higher probability of disturbing effects of external noise which is increasing with measurement duration. The airborne sound attenuation tends to decrease with increasing measurement duration.

5. ACKNOWLEDGEMENTS
We acknowledge all participants for contributing their results.

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