Design Principles of the Italian Round Robin Test on Reverberation Rooms

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ABSTRACT

This paper describes the design principles underlying the Round Robin Test (RRT) carried out among the laboratories of the Sound Absorption working group of the Italian Standardization Body (UNI). In recent years, the determination of the measurement uncertainties in the fields of building and room acoustics has attracted increasing attention. In particular, sound absorption in a diffuse sound field might be difficult to determine, especially for very highly absorptive materials. Results coming from different laboratories cannot always be compared, due to differences in the actual sound field found in nominally equivalent facilities. During this RRT, carefully selected samples have been measured in the reverberation rooms of the different laboratories participating in the RRT according to standard ISO 354 in force as well as the newly proposed draft. The procedure will be presented in the paper.

Keywords: Sound absorption, Reverberation room, Round Robin Test, ISO 354

1. INTRODUCTION

Measurement of sound absorption of materials and objects under diffuse field conditions is normally carried out (with the exception of some countries having alternative standards), according to ISO 354 "measurement of sound absorption in a reverberation room" (1).

It is well known that there are many issues regarding the sound absorption measurement in a reverberation room, such as the diffusivity of the sound field (2, 3), the presence of diffusers (4), the use of the Sabine formula and the edge effect (5). With reference to the latter effect, the standard suggests some mitigating actions, and others have been developed in the scientific literature with

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reference to larger samples (6, 7), but the problem still lacks a definitive solution. All the above-mentioned issues lead to an increase in the dispersion of results (8) of sound absorption coefficient among laboratories.

ISO 354 is currently under review (9) and many changes are proposed with the main purpose of improving the reproducibility of the results.

However, the effects of these changes have not been studied in deeper detail and therefore, before expressing its agreement to the changes, the Italian Standardization Body mirror group (UNI/CT002/SC01/GL09) of ISO/TC43/SC02/WG35 decided to perform a Round Robin Test (RRT) in order to have experimental evidences supporting its decision.

Another RRT is ongoing in the frame of the DENORMS cost action (Designs for Noise Reducing Materials and Structures), focusing on low frequencies, starting from 50 Hz (10).

Among the different changes proposed, those included in this RRT deal with:

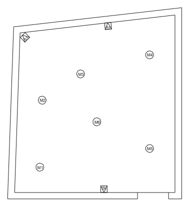
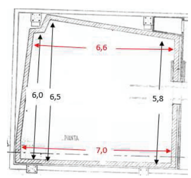
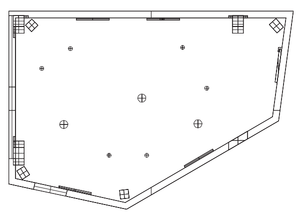
- the use of a reference absorber, to be used to correct calculated absorption coefficients according to the ratio of the measured and expected absorption of the reference absorber;
- the use of T30 instead of T20 for the evaluation of reverberation times based on the decay curves;
- the minimum number of averages: 6 instead of 3, at each microphone/source position when using the interrupted noise method;
- the damping of the room, which implies that the total absorption of the room should be closer to the “maximum” allowed limit;
- the qualification of the room, based on the calculation of the mean value of the ratio between the standard deviation of measured T30 values and a limiting value suggested by the Draft (9), based on researches by Davy (11, 12, 13);
- the sound source positions, which are now supposed to be always located at corners, using specifically designed loudspeakers.

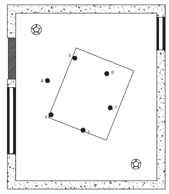
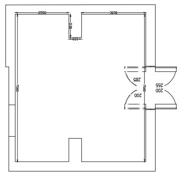
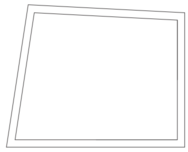
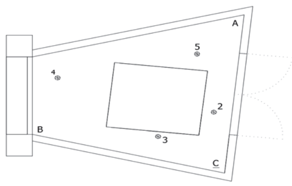
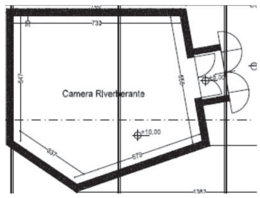
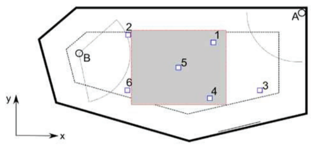
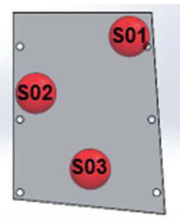
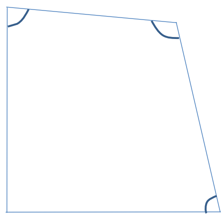
2. ROUND ROBIN TEST DESIGN

2.1 Laboratories

Eleven laboratories agreed to participate in the RRT. The geometric properties such as volumes, floor surfaces and drawings of laboratories are indicated in Table 1, together with the reverberation time (T20) as per ISO 354, of the empty room, averaged from 100 to 5000 Hz.

Table 1 – geometric properties and mean reverberation time of the rooms

Laboratory	Volume, m^3	Floor surface, m^2	Empty room T20, s	Drawings
ITC	219.0	54.9	11.3	
INAIL	187.0	41.6	5.0	
University of Bologna	286.0	83.3	6.4	

Istituto Giordano	218.8	54.9	5.5	
CSI	191.0	42.1	5.8	
University of Padova	211.0	38.0	11.4	
ZetaLab	161.3	43.0	4.7	
Elica, UNIVPM	250.0	49.8	8.4	
DICAR, PoliBA	200.0	45.4	7.3	
University of Ferrara	252.5	49.5	4.6	
INRiM	294.0	59.5	10.0	

2.2 Samples

The samples used for the purposes of a RRT, could consist in one individual object that is sent around the laboratories or in several identical objects sent to the different laboratories. In this RRT, samples from the same production batch were sent to the different laboratories participating in the RRT.

The sample used as reference absorber is a rock wool material, 70 kg/m^3 density, 10 cm thickness, arranged in double-layer with a total thickness of 20 cm. The other samples used for comparison and calculation were a single layer (10 cm thick) of the same rock wool material mentioned above, and a polyester fiber matt, 2 cm thickness, density of 50 kg/m^3.

In order to avoid edge effects, a frame was used for both rock wool samples, 20 cm and 10 cm thickness. The frame was made in plywood, 18 mm thick, exactly as suggested by the ISO Draft (9). The RRT participants agreed not to use a frame for the polyester fiber sample, because of its small thickness.

The surface area of each sample was 10.8 m^2.

2.3 Repetitions

In order to calculate both the inter-laboratory and the intra-laboratory standard deviation, each laboratory participating in the RRT repeated each measurement five times for each sample, as specified in the RRT protocol; one repetition consisted in the measurement of the reverberation time with and without the sample in the room, performed directly one after the other.

When possible, the 5 measurements had to be repeated in the same day, in order to keep the environmental conditions as constant as possible. In any case, temperature, relative humidity and ambient atmospheric pressure were constantly measured and their effect on measured parameters was compensated according to ISO 9613-1 (14).

3. ROUND ROBIN TEST PROTOCOL

A measurements protocol was sent to all laboratories. As the main goal of the RRT is the comparison between the precision of results measured with the standard ISO 354 in force (2003) and the ones measured following the changes proposed in the Draft, the protocol was divided into two main parts: “ISO 354” measurements and “Draft” measurements.

A third additional part, regarding the qualification of the room according to ASTM C423-17 (15) was added, in order to better understand the diffusivity of the sound field in the rooms.

3.1 ISO 354 measurements

Each laboratory had to follow the procedure usually adopted for the measurements according to ISO 354. Each laboratory had to send to the RRT coordinator the following data, for each sample under test, for each repetition:

- the reverberation time for both evaluation ranges, T20 and T30, with and without sample in the room;
- the equivalent absorption area for both evaluation ranges, T20 and T30, with and without sample in the room;
- the environmental conditions: temperature, relative humidity and ambient atmospheric pressure, with and without sample in the room;
- the values of the sound absorption coefficient α_s, the practical absorption coefficient α_p and the weighted absorption coefficient α_w.

3.2 Draft measurements

The Draft prescribes the use of customized loudspeakers positioned in the corners of the room. For the purposes of this RRT, the sound sources (dodecahedrons) normally used for the measurements pursuant to ISO 354:2003 were used in the corner positions. Some laboratories used one single loudspeaker facing the corner of the room.

Each laboratory had to fulfill the following steps:

- damping of the room;
- qualification procedure;
- measurement of the three samples.

Each laboratory had to send to the RRT coordinator the following data:

- materials and method used in order to damp the room;
- the ratio of the measured and theoretical spatial standard deviation, f_d, for both damped and non-damped room (if the case);

- for each repetition and for each sample under test the same data as the one listed in paragraph 3.1, for both damped and non-damped room (if appropriate);
- a set of figures with sound energy decays, in order to estimate the proper signal-to-noise ratio in each significant frequency band (16).

3.2.1 Damping of the room

One of the main changes included in the Draft is the damping of the room.

As in ISO 354 in force, the equivalent sound absorption area A of the empty room shall not exceed the value indicated in Table 2 for a room volume V=200 m^3. It is an open discussion whether these values should or should not be related to the actual room volume, multiplying the value of Table 2 by the well-known formula of ISO 354:

$$(V/200)^{2/3} \tag{1}$$

In the Draft, however, it is recommended to reduce the reverberation time in the room at the lower frequencies to obtain absorption values just below the values given in Table 2 (including the volume correction), for example around 6 m^2 for the frequencies 100-315 Hz.

Therefore, the laboratories participating in the RRT, had to damp their room to fulfill this requirement. However, not all the laboratories had to damp their room, because some of them already had an equivalent absorption area close to the maximum absorption area allowed.

The laboratories that had to damp their room, repeated all the measurements of this part of the protocol (draft measurements) for both damped and non-damped room.

Table 2 – Maximum equivalent sound absorption areas for a room volume V=200 m^3

Frequency, Hz	Maximum A, m^2	Frequency, Hz	Maximum A, m^2
100	6.5	800	6.5
125	6.5	1000	7.0
160	6.5	1250	7.5
200	6.5	1600	8.0
250	6.5	2000	9.5
315	6.5	2500	10.5
400	6.5	3150	12.0
500	6.5	4000	13.0
630	6.5	5000	14.0

3.2.2 Qualification procedure

The qualification procedure included in the Draft (appendix A) had to be performed, with the diffusers in the room, to determine the relative standard deviation of the reverberation time with the reference absorber at the normal measuring position. When using the interrupted noise method, at least 18 reverberation time measurements had to be done for each source-microphone combination.

In the Draft, it is recommended that the ratio of the measured and theoretical spatial standard deviation of reverberation time, f_d, be less or equal to 1.

3.2.3 Reference absorber

The idea behind the use of a reference absorber is that "when using a standard absorber the average result may be used as a reference for correction measurement result of other samples, based on the difference of the measured absorption of the reference absorber and the average absorption of the absorber" (17). The values of the sound absorption coefficient of the reference absorber are indicated in the Draft and shall be used to calculate the absorption correction factor γ. In this RRT, a different material was used instead of the reference absorber (glass wool) indicated in the Draft: the double-layer rock wool, mentioned above. Thus, since the true value of the measurand is not known, it is necessary to use an estimated value, which was assumed to be the inter-laboratory mean value coming from the RRT.

In accordance with the prescriptions of the Draft, the reference absorber value was determined with the damped reverberation rooms. Then, in order to calculate the sound absorption values of the RRT samples (the single-layer rock wool and the polyester fiber) the average sound absorption value of the reference absorber (double-layer rock wool) was first evaluated (best-estimated value), and then used to find the value of the calibration factor γ for each laboratory.

4. CONCLUSIONS

This paper illustrates the design principles of the Italian Round Robin Test on reverberation rooms. The laboratories participating in the RRT are listed, along with their volume and floor surface, and the samples measured are indicated. The type and number of measurements included in the protocol are listed in order to compare the precision of the results obtained following the prescription of ISO 354 in force with that of the results obtained in accordance with the Draft.

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