Some issues in measurement of the random-incidence scattering coefficients in a reverberation room

Young-Ji Choi, Dae-Up Jeong and Ji-Young Kim

Department of Architectural Engineering, Chonbuk National University, JeonJu, Korea

ABSTRACT

The present work tries to investigate the problems and uncertainties of measuring random-incidence scattering coefficients in a reverberation room based on ISO 17497-1. A 1:5 scale model of the reverberation room, which has a volume of 2.4 m³, was employed to measure the random-incidence scattering coefficient for periodic battens. In the present work, three factors, the turntable diameter, the air gap below the turntable and the absorption of test sample were considered. The influence of each factor on the scattering coefficients was measured and analysed. It was found that the turntable diameter influenced the scattering coefficient of the baseplate at frequency bands, 1 kHz to 5 kHz, although the values are within the ranges specified in the ISO standard. An air gap of 50 mm below the turntable results in a high scattering coefficient for the base plate and in a low scattering coefficient for the periodic battens at 1 kHz to 5 kHz. Varying the absorption of the test sample has no significant effect on the scattering coefficients.

INTRODUCTION

Diffusion has been known as one of the most important acoustical attributes in room acoustics and widely applied in controlling the acoustics of rooms. Since the development of QRD diffusers by Schroeder (1975), demands on advanced techniques for designing effective diffusers and proper measurement method have increased. Recently, ISO and AES working group have standardized the measurement procedures for scattering and diffusion coefficients of surfaces, respectively. The scattering coefficient is a measure that describes the degree of scattered sounds from surfaces. Also, it seems practical to be applied to room acoustic simulation models. On the other hand, the diffusion coefficient concerns the directional uniformity of the scattering. Although the standard method for measuring scattering coefficients has already been proposed, only few measurement results have been published. There is still a need for investigating the problems and uncertainties of this method to be applied in room acoustic simulation models. In this paper, the scattering coefficient measurements were carried out in a scale model of the reverberation room, and the results were compared with previous studies. Also, the problems and uncertainties of the ISO standard were discussed.

MEASUREMENTS

The section deals with the details for the measurement setup and procedure used in the present work. The whole process was strictly based on ISO 17497-1 (2004).

The scale model

A 1:5 scale model of the reverberation room (volume: 2.4 m^3) was used to measure the random-incidence scattering coefficients. The scaled model was built using varnished MDF panels (15 mm thick) and no diffuser panel was installed within the scale model. The room was built to have asymmetrical shape in its plan and sections in order to avoid room modal defects due to its symmetrical shape. Preliminary investigation with and without diffuser panel did not show any significant difference in room diffusivity. The volume (V) of the reverberation room is well above the suggested ranges by ISO standard. The volume should be at least 1.6 m³ in a 1:5 scale (in a real scale, V ≥200 m³) according to the ISO standard. The effect of three parameters, turntable diameter, air gap below turntable, and absorption of test specimen on the measured scattering coefficients were examined. For this, the ranges of three parameters in the scale model were varied by employing two different cases for each parameter [see Table 1]. The turntable base plate was made of a varnished MDF panel (15 mm thick). Two cases of air gap below the turntable, 50 mm and 222mm, were examined. The minimum turntable diameter (d) recommended by the ISO standard is 0.60 m ($d \geq 3$ m X N^{-1}, N is a scale factor). The investigated two diameters for the turntable were 0.64 and 0.84 m. The baseplate was supported by small wheels and rotated manually. The scale model of the reverberation room with the periodic battens placed on the turntable is shown in Figure 1.

Table 1. Investigated cases for each parameter in the scale model set-up.

Parameter	Varied value	
Turntable diameter	0.64 m	0.84 m
Air gap below the turntable	50 mm	222 mm
Absorption of test sample	0.11	0.31

To calculate the scattering coefficient, δ, two different absorption coefficients (random incidence absorption coefficient and random incidence specular absorption coefficient) need to be determined (see equation 1). The random-incidence absorption coefficient, α_s, is determined by measuring reverberation time without (T1) and with (T2) the test sample according to ISO 354. The random-incidence specular absorption coefficient, α_{spec}, is determined from the specular impulse responses obtained by rotating the turntable and phase-locked averaging of impulse responses from different sample orientations. The late non-correlated parts will be cancelled by phase-locked averaging of impulse responses and hence impulse responses only contain the specular component of the reflections.

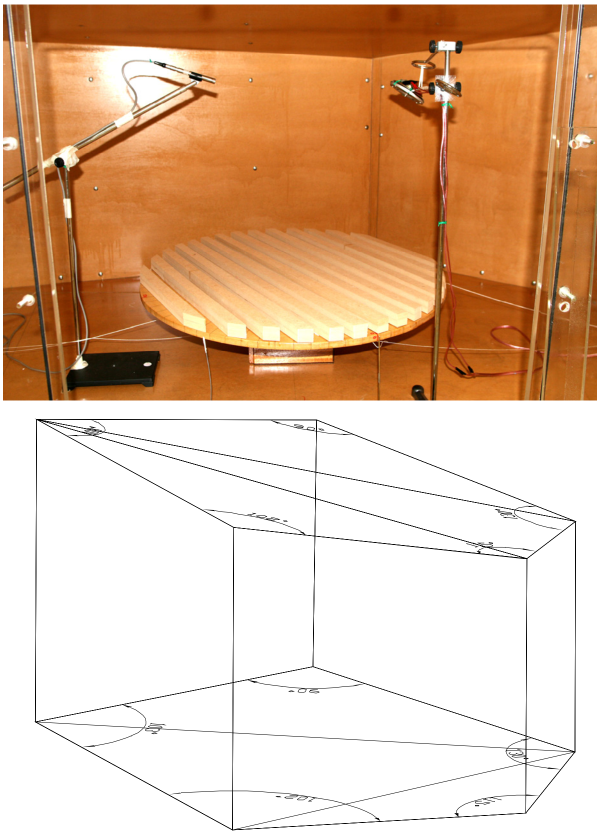

Figure 1. The 1/5 scale and 3D model of reverberation room.

The reverberation times, obtained by rotating the turntable with (T4) and without (T3) the test sample, were used for the calculation of the specular absorption coefficient. The turntable was rated by a fixed step (Δθ=5°) and 72 impulse responses were obtained with each combination of source and receiver position. Two source and three receiver positions were used for measuring impulse responses according to ISO 17497-1. The 72 impulse responses obtained from different sample orientations were phase-locked averaged for each combination of source and receiver position. The reverberation times averaged in six combinations of two source and three receiver positions were used for the calculation of the absorption coefficients. The ISO standard recommends to evaluate the reverberation time within the decay range of -5 dB ~ -20 dB (T15), since the evaluation of early decay part plays a significant role in the suggested standard. It took about 30 minutes to complete one rotation of the turntable for manual stepwise measurements. The temperature and relative humidity were checked throughout the whole measurement process.

$$\delta = \frac{\alpha_{spec} - \alpha_s}{1 - \alpha_s} \qquad (1)$$

The test sample

Two different periodic battens were used in the scattering coefficient measurements (see Figure 1). The test samples have exactly the same dimension (3 cm × 3 cm), while the absorption of each was varied. The absorption characteristics of the test sample were changed by varnishing the surface of battens, which made each batten piece more rigid and reflective. The absorption coefficients of the periodic battens with and without varnishing measured at the centre frequency of 1/1 octave bands were presented in Figure 2.

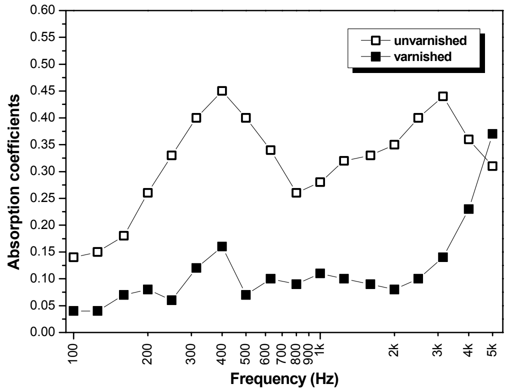

Figure 2. The absorption coefficient of the test sample.

RESULTS AND DISCUSSIONS

The turntable diameter

The effect of changes in the dimension of base plate turntable on the measured scattering coefficients was examined. The turntable was placed at the height of 222mm on the floor of scale model. Two base plate turntables, which have a diameter of 0.64 and 0.84 m, were alternatively installed and the scattering coefficients were measured and compared. For securing the successful measurement environment, the measured scattering coefficients of the turntable should not be exceeded the maximum values specified in the ISO standard (2003). The scattering coefficients measured for each turntable are shown in Figure 2. Although, the ISO standard recommends to evaluate the reverberation time in the first decay range from -5 dB to -20 dB, three reverberation times, T10 (-5 dB ~ -15 dB), T20 (-5 dB ~ -25 dB) and T30 (-5 dB ~ -35 dB) were calculated from Schroeder curve and compared. The scattering coefficients for both turntables are within the ranges suggested in ISO 17497-1. One exception for the turntable, which has a diameter of 0.64 m, is found at 5 kHz, when T30 is used for the calculation.

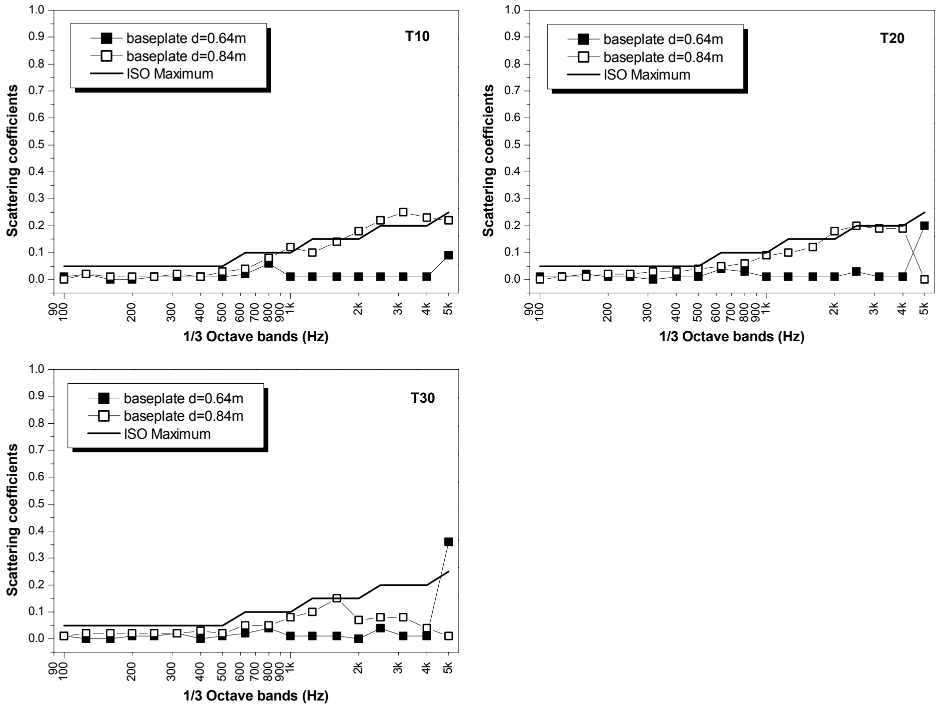

Figure 3. The scattering coefficients for the base plate were compared by changing different diameters (0.64 m and 0.84 m). The applied air gap below the turntable was 222mm.

In this work, the turntable was driven manually but the scattering coefficient of the base plate did not exceed the maximum values at high frequency bands specified in the ISO standard. Vorländer et al (2004) has reported that long measuring times (more than 1 hour for one complete rotation of the turntable) result in overestimated scattering coefficients at high frequencies in real scale measurements. But this was not happened in the present study because reasonable times (30 minutes for one complete rotation of the turntable) were taken during the measurements. The influence of varying the turntable diameter on the scattering coefficient was found at mid and high frequency bands, 1 kHz to 5 kHz. A low variation in the scattering coefficient is found when the reverberation time, T30, is used for the calculation.

The air gap below the table

The effect of air gap below the turntable on the measured scattering coefficients was measured and analysed. Two different air gaps of 50mm and 222mm were applied to the space below the turntable, which has a diameter of 0.84 m. Figure 3 shows the measured scattering coefficients for the turntable when the air gaps below the turntable were varied.

Higher scattering coefficients for the turntable were obtained

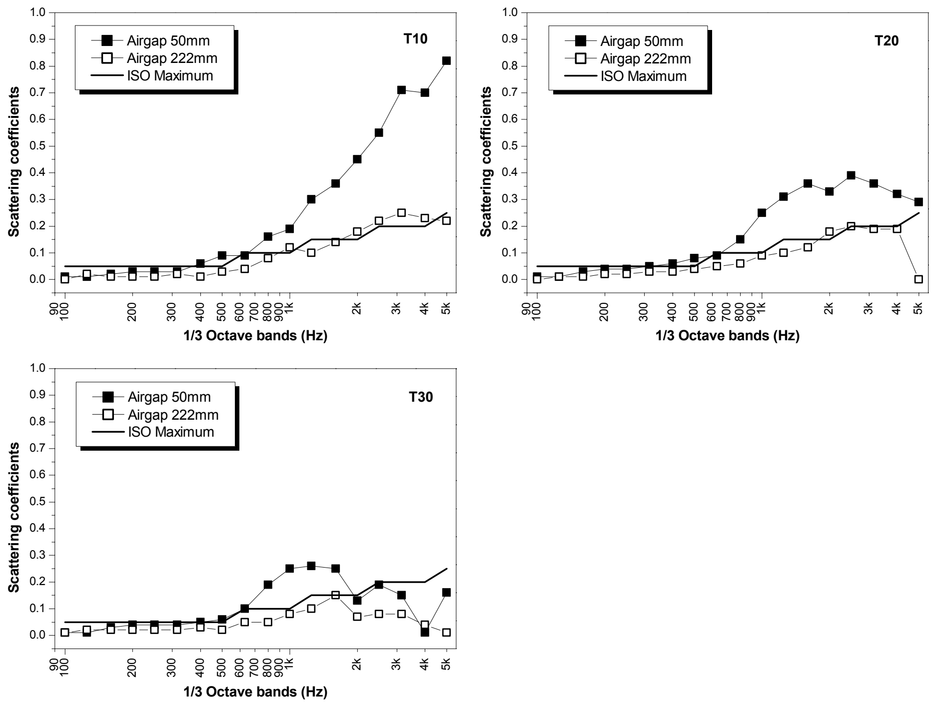

Figure 4. The scattering coefficients for the base plate were compared by changing different air gaps (50 mm and 222 mm). The applied base plate diameter was 0.84 m.

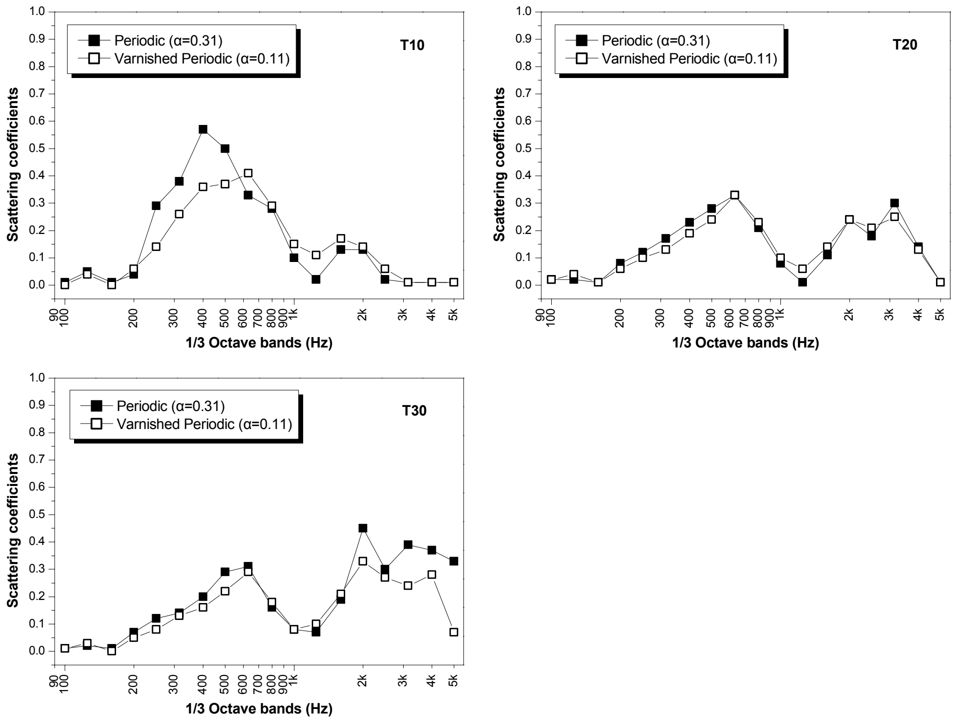

Figure 5. The scattering coefficients for the periodic battens with different absorptions were compared. The base plate diameter was 0.84 m and the air gap below turntable was 50 mm.

at high frequency bands, from 1 kHz to 5 kHz, when the air gap of 50 mm was applied and the reverberation times were drawn out using T10 and T20. Changes in the scattering coefficient for the turntable can be observed when the measurement was carried out with the test specimen installed on the turntable. Figure 4 shows the measured scattering coefficients for the periodic battens by varying the air gap below the turntable. A low scattering coefficient for the periodic battens at frequency bands, from 1 kHz to 5 kHz, were obtained when the air gap of 50 mm employed and the reverberation times, T10 and T20, are used for the analysis. The results are very different compared to the scattering coefficient for the turntable placed over the air gap of 222 mm. A low scattering coefficient for the periodic battens is probably due to the high scattering coefficient of the turntable itself. When the reverberation times, T30, is used for the calculation, a slightly higher scattering coefficient for the periodic battens placed over the air gap of 50 mm is obtained at frequency bands, from 2 to5 kHz.

The absorption of the test sample

The ISO standard recommends applying current measurement method to test specimen whose absorption coefficients are less than 0.50. The scattering coefficients for the periodic battens were measured by varying the absorption of samples. The employed turntable diameter and the air gaps were 0.84

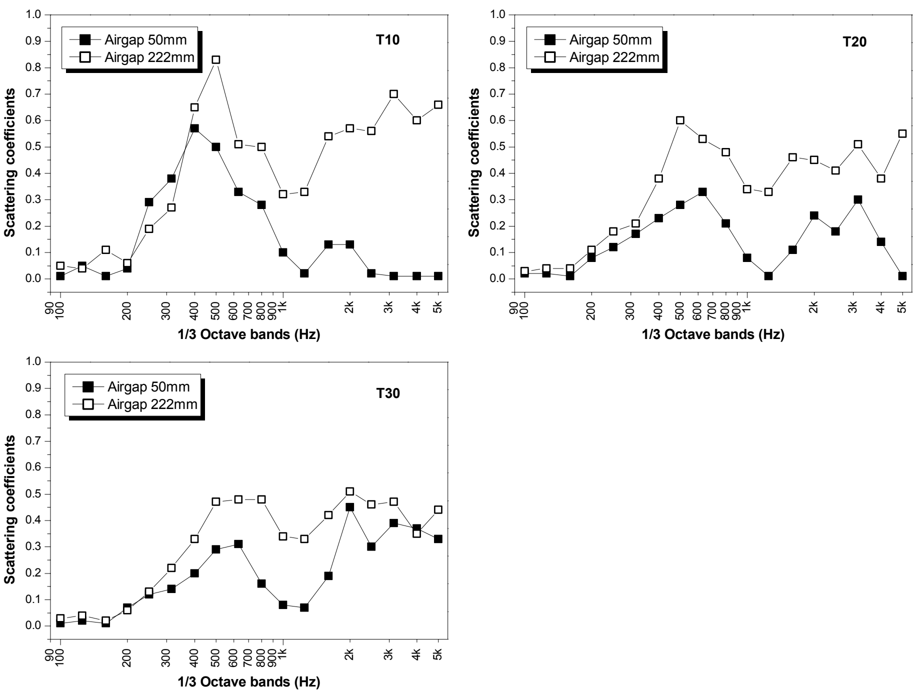

Figure 6. The scattering coefficients for the periodic battens were compared by changing different air gaps (50 mm and 222 mm) below the turntable. The applied base plate diameter was 0.84 m.

m and 50 mm, respectively.

The absorption of the test sample is not likely to have a significant effect on the scattering coefficients. Figure 6 compares measured scattering coefficients of two one dimensional diffusers. They shared exactly the same dimension but different absorptions. A slightly lower scattering coefficient was measured at frequency bands, between 315 and 630 Hz, when the test sample was less absorptive. Again a higher scattering coefficient for the turntable results in low scattering coefficient for the periodic battens at high frequency bands when the reverberation times, T10 and T20, were used for the analysis.

SUMMARY

The present work preliminarily investigated possible problems and uncertainties of measuring scattering coefficients in a scale model according to ISO 17497-1. Scattering coefficient for the periodic battens was measured in the one fifth scale model of the reverberation room. The ranges of three factors, the turntable diameter, the air gap below the turntable and the absorption of the test specimen were varied to see how they influence the measured scattering coefficient.

The results of the present work are summarized as below:

- It was found that the turntable diameter influenced the scattering coefficient of the base plate at high frequency bands (1 kHz to 5 kHz). However, the measured scattering coefficients of both turntables did not exceed the maximum values specified in the ISO standard. Lower scattering coefficients for the turntable were obtained, when the minimum value of 0.64 m for turntable diameter was applied.
- Higher scattering coefficients for the turntable was obtained at high frequency bands (1 kHz to 5 kHz), when the air gap of 50 mm below the turntable was applied. It seems that the high scattering coefficient of the turntable results in the low scattering coefficient of the periodic battens at frequency bands, 1 kHz to 5 kHz.
- The absorption of the test sample doesn't seem to have a significant effect on the measured scattering coefficients. A slightly low scattering coefficient was found with the varnished periodic bettens at low frequency bands, 315 Hz to 630 Hz. Low scattering coefficients for the test samples at 1 kHz to 5 kHz is probably due to the high scattering coefficient of the turntable.

Although the ISO standard for measuring scattering coefficients has already been proposed, there are some issues which should be well specified in the standard for obtaining more reliable measurement results. The ISO standard only specifies the minimum diameter of the turntable. In the present work, the diameter of the turntable had an effect on the scattering coefficients for the turntable at high frequency bands. There should be a specific guideline on the turntable dimensions such as, the thickness and the air gap below the turntable. In particular, there is a significant difference in the scattering coefficients for the turntable when two different air gaps were applied in the measurements. The ISO standard also mentions that a slightly non-symmetrical base plate can result in the scattering coefficients of the turntable itself, but it is not clear what extend this have an effect on the scattering coefficients for the turntable and the test specimen. The scattering coefficient for the test specimen was significantly influenced by the decay ranges being evaluated. Although the ISO standard recommends evaluating the first decay curves from -5 dB to -20 dB, there must be a specific guideline how to evaluate the decay ranges, especially when there exist double slopes within the decay process.

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