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The effect of an edge on the measured scattering coefficients in a reverberation chamber based on ISO17497-1

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ABSTRACT

The scattering coefficient has been regarded as one of the important factors to be considered in the acoustic design of a room. ISO 17497-1 provides a method for measuring the random-incidence scattering coefficients in a reverberation chamber. However, the uncertainties of this method due to the lack of details with respect to the measurement conditions have been reported. It is necessary to provide more specific guidelines for this method. The present study suggests an improved measurement method by investigating the edge effects. The scattering coefficients of a simple 1-dimensional diffuser were measured in a 1/5 scale model of the reverberation chamber based on ISO 17497-1. The effects of an edge stripe on the scattering coefficients were measured and analysed. Further, several issues with respect to the sample diameter, the air gap below the turntable and the absorption of the test sample were discussed.

INTRODUCTION

In order to verify the practical usages of the diffuse field method for measuring the scattering coefficient based on ISO 17497-1, a few studies have been carried out [1-4]. ISO 17497-1 provides a method for measuring the random-incidence scattering coefficient in a reverberation chamber [5]. However, uncertainties of the measurement results due to the lack of experimental details with respect to the measurement conditions have been reported [4]. It is necessary to yield more specific guidelines for this method. The present study attempts to investigate the uncertainties of the measurement method by examining the edge effects on the measured scattering coefficients.

In the present work, the scattering coefficients of a simple 1-dimensional diffuser were measured in a 1/5 scale model of the reverberation chamber. The effects of an edge stripe on the scattering coefficients were measured and analysed. Further, several experimental conditions with regard to the sample diameter, the air gap below the turntable and the absorption of the test sample were examined.

MEASUREMENTS

Scale model set-up

In the 1/5 scale model of a reverberation chamber, the specifications based on ISO 17497-1 were employed. Those are the volume of the reverberation room, the minimum sample diameter, the minimum distance to the walls of the room, the structural depth of test sample, the absorption coefficient of the test sample and the number of coherent averages. Table 1 presents the specifications given in the ISO standard. Figure 1 shows the 1/5 scale model of a reverberation chamber. In the 1/5 scale model of the reverberation chamber, log swept sine signals were used. Six combinations of two source positions and three receiver positions were used in the measurements. The length of test signal was 1.37 seconds. The compensation of air absorption in the scale model was dealt with by substituting the air with nitrogen. The relative humidity was approximately 11% throughout each measurement.

Figure 1. A 1/5 scale model of the reverberation chamber.

A repeatability test of measurements for the scattering coefficient of the test specimen was implemented to examine whether the results were consistent for each measurement. In all, nine measurements were carried out; the standard deviations after nine measurements showed that the repeatability of the measurements was reliable in the corresponding full-scale frequency bands from 100 Hz to 5 kHz. Therefore, the measurements were repeated three times and the results were presented as the mean scattering coefficient with its standard deviation.

Table 1. Specifications given in ISO 17497-1 [5].

Parameter	ISO standard	1/5 scale model
Reverberation room volume(m^3), V	$V \geq 200 \times N^{-3}$	$V \geq 1.6$
Base plate diameter(m), d	$d \geq N^{-1} \times 3$	$d \geq 0.6$
Minimum distance to the walls of the room (m), e	$e \geq N^{-1} \times 1$	$e \geq 0.2$
Structural depth of the test sample (m), h	$h \leq d/16$	$h \leq 0.04$
Absorption coefficient of the test sample, α_s	$\alpha_s \leq 0.5$	$\alpha_s \leq 0.5$
The number of coherent averages, n	$60 \leq n \leq 120$	$n = 72$ ($\Delta ø$=5°)

Table 2. Measurement equipment.

Equipment	Model	Manufacturer
Loudspeaker	XT25TG30-04	Vifa
Loudspeaker amplifier	AX-5030R	Inkel
1/2 inch microphone	Type 4191	B&K
Microphone preamplifier	Type 26AK	G.R.A.S
Conditioning amplifier	Type 2829	B&K
A/D board	Lynx L22	Lynx Studio Technology Inc.
Measurement software(Dirac 4.1)	TYPE 7841	B&K
Turntable	LR 360	LinearX Systems

ISO 17497-1

The ISO 17497-1 [5] refers to the way of measuring the random-incidence scattering coefficient in a reverberation room. The basic idea of the proposed ISO measurement technique consists of the recording of a series of impulse responses for different angle positions of a circular test sample on a centrally rotating base plate. By synchronous averaging of these impulse responses, a virtual impulse response can be obtained which relates only to the specular component of the reflected energy. The reverberation time should be obtained from impulse response measurements under four different conditions (see Table 3). A scattering coefficient can be calculated from the differences in reverberation time. The measurement should be performed in one-third-octave bands with centre frequencies covering the frequency range from 100 Hz to 5,000 Hz in either a full-scale or reduced-scale reverberation room.

$$\alpha_s = 55.3\,\frac{v}{s}\left(\frac{1}{c_2T_2} - \frac{1}{c_1T_1}\right) - \frac{4v}{s}(m_2 - m_1) \qquad (1)$$

$$\alpha_{spec} = 55.3\,\frac{v}{s}\left(\frac{1}{c_4T_4} - \frac{1}{c_3T_3}\right) - \frac{4v}{s}(m_4 - m_3) \qquad (2)$$

$$s = 1 - \frac{1-\alpha_{spec}}{1-\alpha_s} = \frac{\alpha_{spec} - \alpha_s}{1-\alpha_s} \qquad (3)$$

Where, c_n: the speed of sound in air (m/s), during the measurement of T_n.
m_n: the energy attenuation coefficient of air (m^{-1}), during the measurement of T_n.
T_n: the reverberation time obtained for the measurement condition in Table 3.

With respect to the test arrangement in the reverberation room, the standard specifies the minimum volume of the room, the minimum absorption in empty room. Also, the shape and the dimension of a base plate as well as a turntable are required to be within the ranges. Please refer to Table 1 for specifications given in the ISO method.

Table 3. Measurement conditions for the four different reverberation times in ISO 17497-1.

Reverberation time	Test sample	Turntable
T_1	not present	not rotating
T_2	present	not rotating
T_3	not present	rotating
T_4	present	rotating

Three experimental conditions for measuring scattering coefficients

The scattering coefficients of the samples both with and without an edge strip around the perimeter of the sample were measured. For the cancellation of the edge effect due to the exposed sides along the perimeter of the test sample, an edge strip made of rigid and reflective materials (3.0mm-thick acrylic panels) were used in the measurements. Figure 2 shows both samples with and without an edge strip.

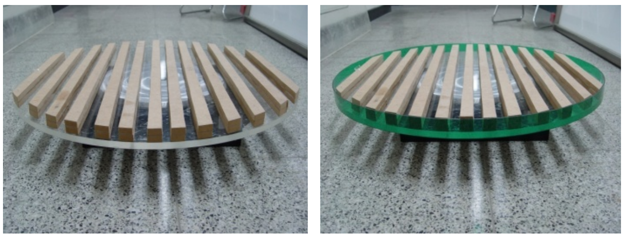

Figure 2. Samples of the periodic battens (left: samples without an edge strip, right: samples with an edge strip).

In the measurements, firstly three cases of the sample diameter (0.64 m, 0.74 m, 0.84 m in reduced-scale) were examined. The base plate was made of a 15-mm-thick of rigid and reflective acrylic panel. For the simple 1-dimensional diffuser, periodic battens ($w \times h$ =0.03 m×0.03 m in reduced-scale) were made of MDF (medium density fibre board) panels and had an interval of 0.03 m between each batten.

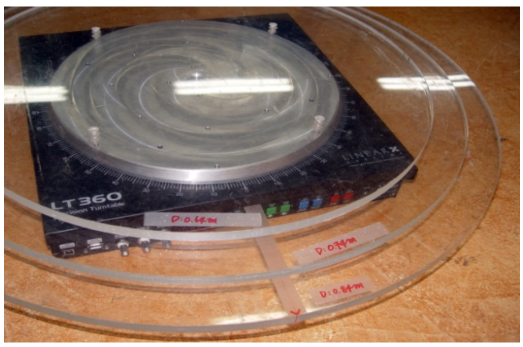

Figure 3. Three cases of the sample diameter (0.64 m, 0.74 m, 0.84 m).

The second parameter concerns the air gap below the turntable. This parameter shall be considered because there are a variety of turntables available from different manufacturers. The effect of this on the scale-model measurements has received little attention. In order to verify the effect of the air gap below the turntable, rigid and reflective 10-mm-thick acrylic panel were placed below the turntable. Figure 4 shows the five air gaps of 105 mm, 125 mm, 145 mm, 165 mm and 185 mm (in reduced-scale).

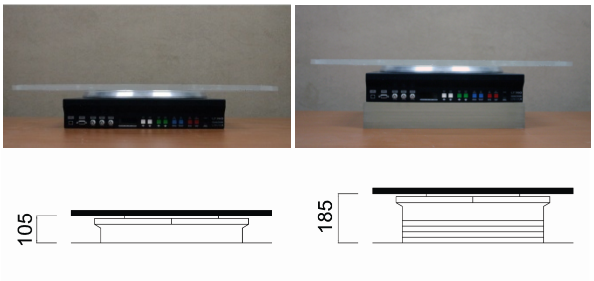

Figure 4. The variations of the air gap below the turntable ranged from 105 mm to 185 mm.

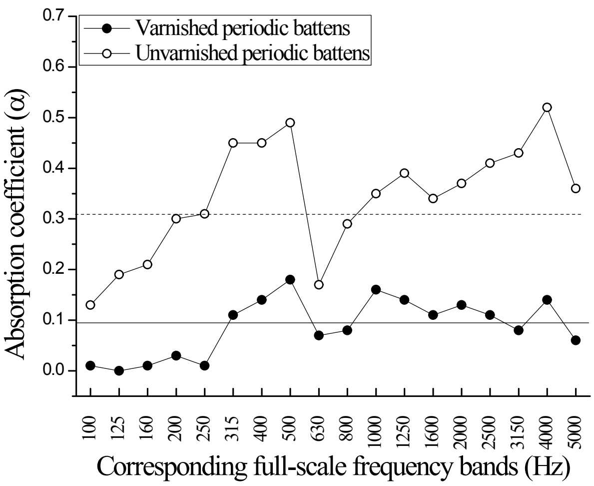

Figure 5. Absorption coefficients of the varnished and unvarnished periodic battens. Solid and dashed lines indicate the frequency-averaged absorption coefficients of varnished and unvarnished periodic battens, respectively.

The third parameter is the absorption of the test sample. The absorption coefficients (α_s) of the samples were varied by varnishing and unvarnishing surface of the samples. The absorption coefficients of test sample in ISO 17497-1 shall be below 0.5. Figure 5 shows the absorption coefficients of the unvarnished and varnished periodic battens.

RESULTS AND DISCUSSION

The sample diameter

Firstly, the effect of sample diameter on the scattering coefficient of the test specimen was implemented. Figure 6 presents the scattering coefficients of the unvarnished periodic battens measured with the three sample diameters when a sample without an edge strip was used. The air gap below the turntable was 105 mm. The variations in the scattering coefficients of the unvarnished periodic battens as a function of the sample diameter were not systematic. Some of the scattering coefficients measured with the sample without an edge strip were greater than 1.0 in the 4-kHz and 5-kHz octave bands. The sample diameter of 0.64 m tends to overestimate scattering coefficient at 500 Hz, 630 Hz, 1.6 kHz and 2 kHz due to the edge effect.

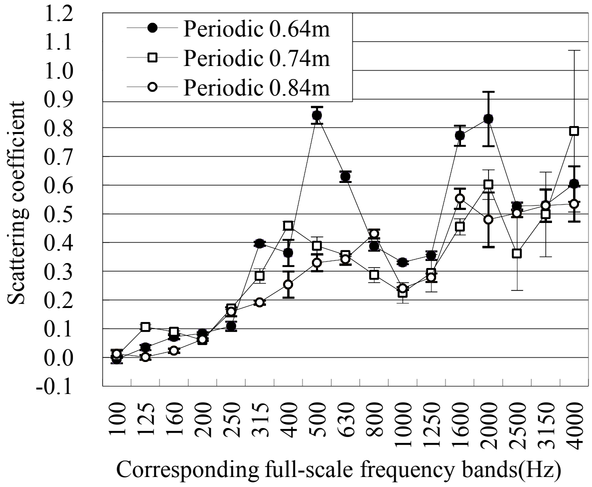

Figure 6. Scattering coefficients of unvarnished periodic battens, measured with three different sample diameters (Sample without edge strip, air gap 105 mm).

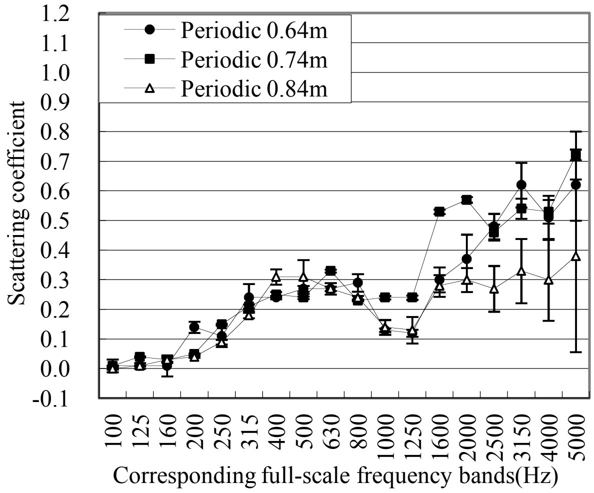

Figure 7. Scattering coefficients of unvarnished periodic battens, measured with three different sample diameters (Sample with an edge strip, air gap 105 mm).

To minimize the edge effect due to the exposed sides along the perimeter of the sample, an edge strip was installed and the unvarnished periodic battens were measured (see Figure 7). Figure 7 shows that some of the overestimated scattering coefficients for the sample diameter of 0.64 m were corrected. The scattering coefficients at mid- and high-frequencies show lower values. The scattering coefficients measured with an edge strip along the perimeter of the sample showed a different trend compared those measured without an edge strip. The highest scattering coefficients were obtained for the sample diameter of 0.64 m when the sample without an edge strip was used, while the values for the sample diameter of 0.74 m indicated the highest scattering coefficients when the sample with an edge strip was used. This is mainly due to the edge effect.

The air gap below the turntable

Figure 8 shows that the scattering coefficients of the unvarnished periodic battens measured with the five cases of the air gap below the turntable. In the measurements, the sample diameter was taken to be 0.84 m. As shown in Figure 8 the scattering coefficient for the air gap of 125 mm at 5000 Hz is higher than 1.0. The scattering coefficients increased with an increase in the air gap below the turntable and larger variations were found for the values at the mid and high frequencies; this was in good agreement with previous research. [4] This suggests that air gap below the turntable should be low.

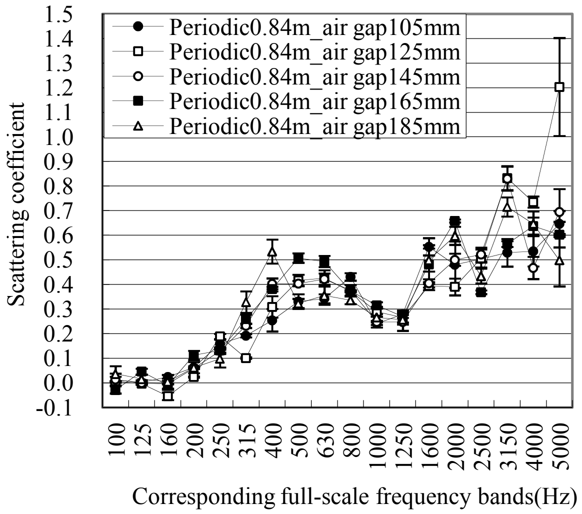

Figure 8. Scattering coefficients of unvarnished periodic battens, measured with five different air gaps (sample without an edge strip, sample diameter 0.84 m).

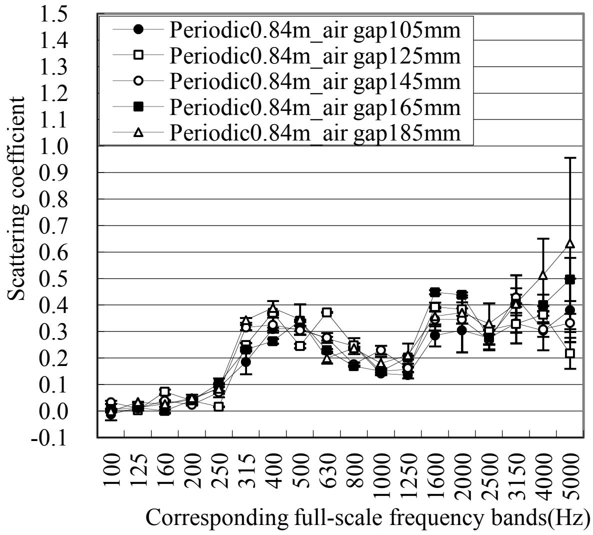

Figure 9. Scattering coefficients of unvarnished periodic battens, measured with five different air gaps (sample with an edge strip, sample diameter 0.84 m).

Figure 9, there is a significant effect of the edge strip on the scattering coefficients at all frequencies. Some of the overestimated scattering coefficients were corrected at higher frequencies. An alternative for minimizing the turntable diffraction due to the air gap below the turntable would be to recess the turntable within the floor of the reverberation room.

The absorption of the test sample

Figure 10 shows the scattering coefficients of the unvarnished and varnished periodic battens measured without an edge strip. The sample diameter of 0.84 m and the air gap below the turntable of 105 mm were used. In Figure 10, the inconsistent values of the scattering coefficient due to the edge effect are noticeable at high frequencies and those values for the varnished periodic battens are higher than 1.0. Further, higher values of the scattering coefficients of the varnished periodic battens were obtained than those from the unvarnished periodic battens; the differences were the greatest at high frequencies from 1.6 kHz to 4.0 kHz and lower scattering coefficients were obtained in the frequency bands from 250 Hz to 630 Hz.

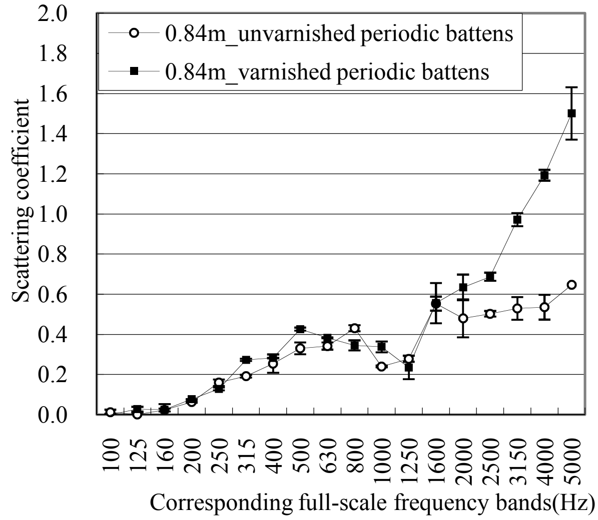

Figure 10. Scattering coefficients of the unvarnished and varnished periodic battens (sample without an edge strip, sample diameter 0.84 m, air gap 105 mm).

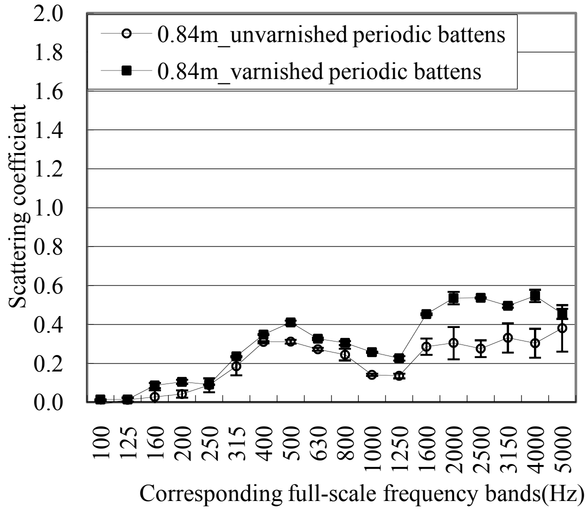

Figure 11. Scattering coefficients of the unvarnished and varnished periodic battens (sample with an edge strip, sample diameter 0.84 m, air gap 105 mm).

Figure 11 shows the scattering coefficients of the unvarnished and varnished periodic battens measured with an edge strip. The values of scattering coefficient higher than 1 were corrected at 4000 Hz and 5000 Hz. In general, larger standard deviations on the scattering coefficients were observed for the unvarnished periodic battens than those for the varnished periodic battens. It is clear that the variations of the absorption coefficients at a certain structural depth lead to a large effect on the scattering coefficients at high frequencies. The repeatability of the measurement results was improved when a more rigid and reflective sample was used.

Conclusion

In this study, unspecified experimental conditions of measuring scattering coefficients in the reverberation chamber based on ISO 17497-1 were investigated. The parameters concerned in the present study were the effects of the sample diameter, the air gap below the turntable and the absorption coefficients of the test sample on the measured scattering coefficient. The results clearly show that the three parameters have a large effect on the measured scattering coefficients at mid- and high-frequencies. Further, the higher scattering coefficients caused by the edges of samples were corrected by using an edge strip around the perimeter of the sample. It was found that the edge strip had a considerable influence on the scattering coefficients at all frequency bands. However, ISO 17497-1 specifies that “do not cover the perimeter with a rigid border of fixed height”. This is likely to be inaccurate in accordance with the results obtained from the present study.

The results of the present work were limited to the scale-model measurements and no comparisons with full-scale measurements and theoretical results were carried out. Full-scale measurements have to be carried out in order to compare the results of the full-scale and the model-scale arrangements of the same experimental conditions to verify the findings from this study.

ACKNOWLEDGMENTS

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