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Comparison the Sound Absorption Rate of Mandarin Peel – Sawdust Composite Boards Measured by Transfer Function Method with by Reverberation Room Method

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The sound absorption rates of mandarin peel – sawdust composite boards with the density of 0.4 g/cm^3 and the mandarin peel content of 40 percent, measured by reverberation room method and transfer function method, were compared in this study. The results of this study were as follows: The sound absorption rate measured by transfer function method was about 10 percent lower than that of reverberation room method due to sound reflective silicon O–ring, however, generally the sound absorption rates measured by both transfer function method and reverberation room method were almost same. Therefore, it is advised that the sound absorption rate can be measured by transfer function method due to its convenience in preparing specimens, less consumption of specimens and quickly measurement.

Key words: Sound absorption rate, Transfer function method, Reverberation room method

INTRODUCTION

Recently, the heightened interest in improving the quality of life has significantly increased demand for control of the noise in residential environment because environmental noise was getting more serious problem. Accordingly, study on the building materials with excellent sound absorption performance and on measurement of sound absorption has increasing.

Sound absorption rate was shown in the ratio of absorbed energy of sound to incident energy of sound, and classified into normal incident sound absorption rate, oblique incidence sound absorption rate, and trespasser incidence sound absorption rate. Actual sound absorption rate was the trespasser incidence sound absorption rate of incidence of sound wave in all directions of reverberation room measured by reverberation room method, and most accurately represented sound absorption of material from incident sound in several directions among three kinds of sound absorption rates. However, it was difficult to measure the actual sound absorption rate. In order to measure trespasser incidence sound absorption rate, a room with the space of above 210 m^3 and the specimen with the area of above 10 m^2 ~12 m^2 were needed when reverberation room method was used. Moreover, the walls in reverberation room should reflect sound to maximum to obtain diffused sound field, and effect of temperature and humidity in the room on sound should be also considered. On the other hand, reverberation tube method was widely used to measure normal incident sound absorption rate due to convenience in preparing specimen and repeatability of test etc. The reverberation tube method was divided into standing wave ratio method and transfer function method, and could simply measure the sound absorption efficiency of small specimen using impedance tube. During standing wave ratio method being used, the pure sound of a single frequency in signal generator was generated and the sound absorption rate of material was measured by measuring the standing wave ratio in the tube. It was drawback for this method that measuring standing wave ratios for each frequency needed long time. The transfer function method was to measure the sound absorption rate of material by the transfer function occurred between two microphones which were adjacent to each other. It was the advantage of this method that sound absorption rate in broad frequency band could be measured quickly using white noise mixed pure sound in broad frequency band from sound source.

MATERIALS AND METHODS

Specimen Preparation

Radiata pine (*Pinus radiata*) sawdust and mandarin peels were dried to the moisture content of 9 percent and pulverized using a crusher, and then screened using a 20 mesh wire screen, respectively. Screened sawdust, mandarin peel, and urea–formaldehyde resin (solids content of 60 percent, E1) were mixed and then hot pressed at 150°C to form composite boards. The hot pressing was performed in three steps, first at a pressure of 4412.993 kPa for 9 min., then at 3432.328 kPa for 2 min., and finally at 1961.330 kPa for 1 min., with a total press-

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ing time of 12 min.. Mandarin peel –sawdust composite boards with the dimension of 35 cm × 35 cm × 1.1 cm were manufactured using a stainless–steel four square mold with 10 percent of resin content, 0.5 g/cm^3 of target density, and 30 percent of mandarin peel content as percent weight of the boards. Specimens were prepared 5 pieces of boards for sound absorption rate test, and 5 pieces of cylindrical specimens for impedance tube.

Measuring sound absorption rate by reverberation room method

The structure of the reverberation room was in the indeterminate shape of heptahedron room with reinforcement concrete structure, 250 mm in wall thickness, 209.7 m^3 of volume, and 15 m^2 of the sound diffuser attached on the ceiling of the room. The area of installation for specimens was 10.24 m^2 (2,833 mm width × 3,615 mm length). The mandarin peel – sawdust composite boards with the dimension of 315 mm width × 315 mm length × 11 mm thickness were arranged into the form of 90 × 11 on the area of installation, and the edge surface of whole specimen was sealed with metal frame as shown in Figure 1. The temperature and relative humidity inside reverberation room were 20.4 ± 0.8˚C, 47.1 ± 3.0 percent in empty room, and 19.2 ± 1.1˚C, 51.6 ± 3.5 percent when specimens were installed.

The pure sound was generated as central frequency of one–third octave band in the range of 100 Hz ~ 5000 Hz using loudspeaker DO12 which generated noise, and falm. The reverberating time was measured using 1/2" condenser microphone, real time analyzer PAK MK Ⅱ, power amplifier CONA V2–5000, and inter–M (G. R. A. S company). As shown in Figure 1 and Figure 2, the reverberating time was measured at 6 positions, 1.5 m of distance between omnidirectional microphones, which were above 1 m from the surface of specimen, from two different sound resources inside the reverberation room 2 m away from sound resource. The time required to attenuation of the acoustic energy of 60 dB, due to pure sound being generated as central frequency of one–third octave band in the range of 100 Hz ~ 10000 Hz, was measured. The sound absorption rate was calculated as follows:

$$\alpha_s = \frac{A_T}{S}$$

$$A_T = A_2 - A_1 = 55.3\,V\left(\frac{1}{c_2 T_2} - \frac{1}{c_1 T_1}\right) - 4V\,(m_2 - m_1)$$

$$c = (331 + 0.6\,t/^{\circ}C)\ m/s$$

Here

A_2: equivalence area of sound absorption of reverberation room including specimen

A_1: equivalence area of sound absorption of empty reverberation room

V: volume of empty reverberation room

c_2: the velocity of sound in air after installation of specimen (m/s)

c: (331+0.6t/˚C)m/s, t: temperature of air (˚C)

T_2: reverberating time inside reverberating room after installation of specimen (s)

T_1: reverberating time inside empty reverberating room (s)

m_2: power attenuation coefficient inside reverberating room during installation of specimen

m_1: power attenuation coefficient inside empty reverberating room during installation of specimen.

Measuring sound absorption rate by transfer function method

The sound absorption rate in practical frequency range was measured by transfer function method using impedance tub, pulse analysis equipment and a spectrum analyzer (B&K company) as precious research (Kang *et al.*, 2012). When sound absorption rate was measured, the diameter of impedance tube was limited by frequency, generally the diameter was 29 mm for high

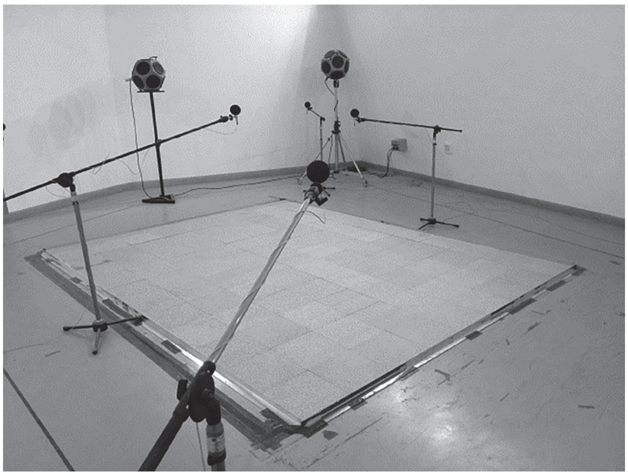

Fig. 1. Photograph of sound absorption coefficient measuring apparatus for reverberation room method.

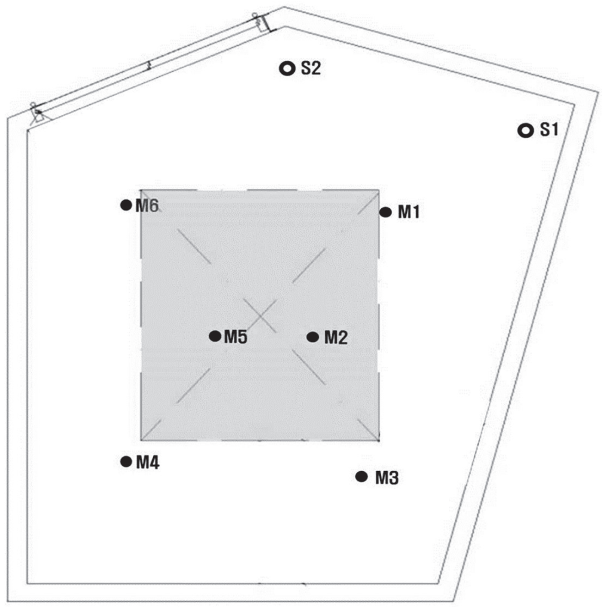

Fig. 2. Schematic diagram of sound absorption coefficient measuring apparatus for reverberation room method.

frequency domain and 99 mm for low frequency domain. In this study, the variation of sound absorption rate was measured as change of frequency in the range of 500Hz ~ 6.4 kHz using the impedance tube with the diameter of 29 mm. And moreover, a silicon O–ring was installed in front of sound incidence surface to reduce the influence of the air gap between specimen and impedance tube. During measurement, temperature, relative humidity and atmospheric pressure were 24.5˚C, 47 percent and 1005.5 hPa, respectively. Moreover, the velocity of sound, air density and acoustic impedance were 345.86 m/s, 1.175 kg/m^3 and 406.3 Pa/(m/s), respectively.

RESULTS AND DISCUSSION

Sound absorption rate of reverberation room method

The sound absorption rate of mandarin peel –sawdust composite boards with the density of 0.4 g/cm^3, and the mandarin peel content of 40 percent was obtained from the reverberation times calculated before and after installation of the specimen with the area of 10 m^2 on reverberation room, as shown in Figure 2. The average reverberation time calculated from microphones at 6 locations, during the pure sound of central frequency of octave band was generating from first speaker, is presented Table 1. It was determined that there was differences in reverberation times before and after acoustic materials being installation because differences in reverberation times was 7 second around the frequency of 500 Hz while that was 1 second~2 second in low frequency. The acoustic absorption coefficients calculated from differences in reverberation times are displayed in Figure 3. Each graph in Figure 3 showed the sound absorption rate calculated from microphones at 6 locations of the pure sound occurred at two speakers. As showed in Figure 3, the acoustic absorption coefficients showed below 0.3 in low frequency range of 400 Hz, and presented above 0.4 in the frequency range of above 500 Hz. It indicates that the sound absorption rate of mandarin peel – sawdust composite boards is increasing with increasing of frequency, which is a typical characteristic of porous sound absorber. The noise reduction coefficient (NRC) showed a value of 0.34.

Table 1. Reverberation time

Frequency (Hz)	T_1 (S)	T_2 (S)
100	23.03	20.38
125	17.65	16.37
160	16.59	13.85
200	14.92	11.26
250	15.36	10.37
315	14.36	7.93
400	13.28	6.19
500	12.11	5.03
630	10.51	4.40
800	9.58	4.19
1000	8.84	4.04
1250	7.20	3.67
1600	6.32	3.43
2000	5.57	3.22
2500	4.51	2.84
3150	3.69	2.47
4000	3.06	2.15
5000	2.38	1.77

Notes: T_1: Reverberation time of empty room, T_2: Reverberation time of after install specimen

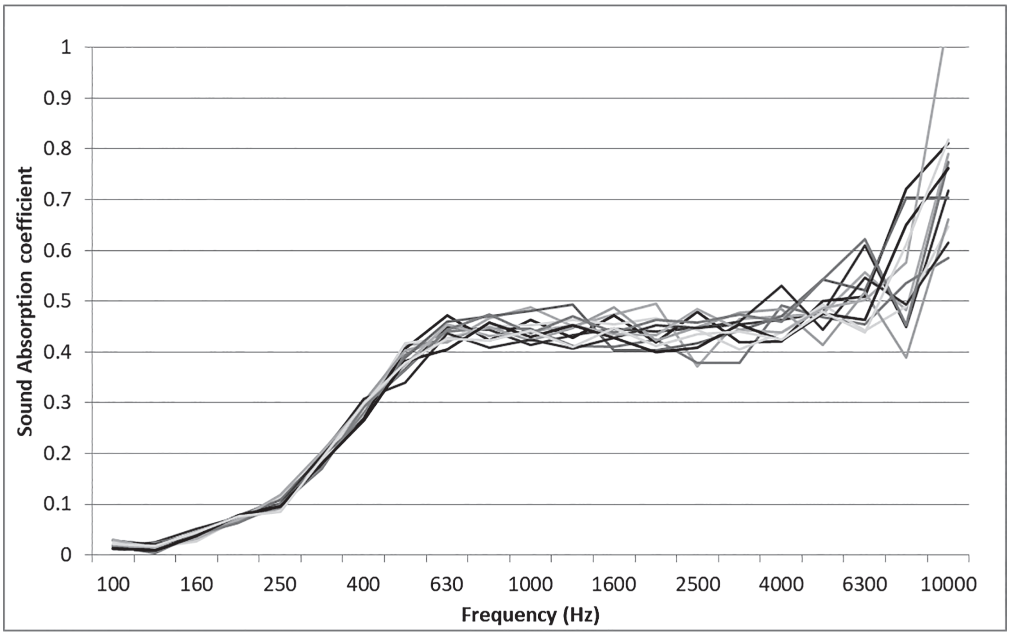

Fig. 3. The acoustic absorption coefficients of mandarin peel – sawdust composite boards by reverberation room method.

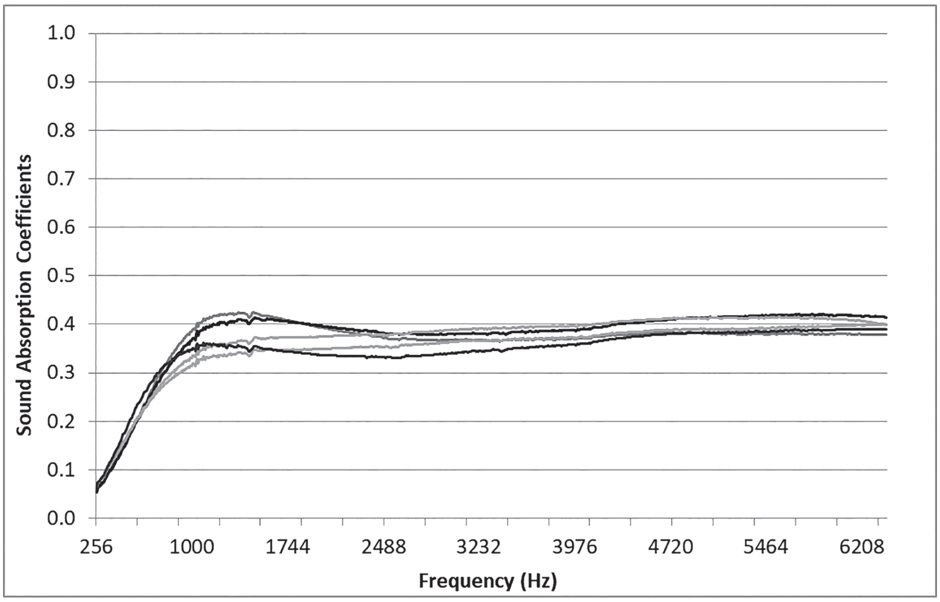

Fig. 4. The acoustic absorption coefficients of mandarin peel –sawdust composite boards by transfer function method.

Sound absorption rate of transfer function method

Sound absorption rates of mandarin peel –sawdust composite boards by transfer function method in the frequency range of 250 Hz ~ 6.4 kHz are presented in Figure 4. The x–axis presented measured frequency, however, this was continuous, which is different from that in reverberation room method. This is due to whole frequency in measuring range being used by the sound with white noise during transfer function method being implemented. As shown in Figure 4, the sound absorption rates showed 62 percent in the frequency band of 2 kHz ~ 3 kHz, however, showed 66 percent in the frequency band of above 3 kHz. The tendency that sound absorption rates was increasing presented more obviously in high frequency band than in low frequency band. This is typical absorption characteristic of porous material. The noise reduction coefficient presented 0.33, which indicates that there is no large differences in sound absorption rates between transfer function method and transfer function method.

The sound absorption rate estimated by transfer function method was about 10 percent lower than that of reverberation room method. This can be ascribed to the sound reflective silicon O–ring because the less part of specimen was exposed sound in transfer function method compared to reverberation room method owning to the sound absorption rate of silicon being low. However, generally, the sound absorption rate measured by transfer function method was almost same as that by reverberation room method, thus it is advised that the sound absorption rate can be measured by transfer function method due to its convenience in preparing specimen and repeatability of test, quickly measurement etc.

It is expected that mandarin peel –sawdust composite boards can be used as sound–absorbing materials such as ceiling material and wallboard because the sound absorption rate of the board above presented higher value than that of gypsum board.

CONCLUSIONS

The trespasser incidence sound absorption rate measured by reverberation room method, and the sound absorption rate measured by transfer function method, of mandarin peel – sawdust composite boards were compared in this study. The results of this study were as follows:

1. The sound absorption rate estimated by transfer function method was about 10 percent lower than that of reverberation room method due to the sound reflective silicon O–ring, however, generally, the sound absorption rate measured by transfer function method and reverberation room method was almost same, thus it is advised that the sound absorption rate can be measured by transfer function method due to its convenience in preparing specimen and repeatability of test, quickly measurement etc.
2. The mandarin peel –sawdust composite boards are suited to be used as sound–absorbing materials owning to their good sound absorption rate.

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REFERENCES

Brian, F., G. Katz 2000 Method to resolve microphone and sample location errors in the two–microphone duct measurement method. *Journal of the Acoustical Society of America*. **108**: 2231

Boonen, R., P. Sas 2004 Calibration of the two microphone transfer function method to measure acoustical impedance in a wide frequency range. *Proceedings of ISMA*. **2004**: 325–33

Chung, J. Y., D. A. Blaser 1980 Transfer function method of measuring in–duct acoustic properties. *J. Acoust. Soc. Am*., **68**: 907–921

CW, Kang., Kim. GC., Park. HJ., Lee. NH., Kang. W and J. Matsumura 2010 Change in permeability and sound absorption capability of yellow poplar wood by steam explosion treatment. *J. Fac. Agr., Kyushu Univ*., **55**: 327–332

CW, Kang., Oh. SW., Lee. TB., Kang. W and J. Matsumura 2012 Sound absorption capability and mechanical properties of a composite rice hull and sawdust board. *Journal of Wood Science*. **58**:273–278

HM, Park., Lee. SK., Seok. JH., Choi. NK., Kwon. CB., Heo. HS., Byeon. HS., Yang. JK and Kim. JC 2011 Effect of green tea content on dynamic modulus of elasticity of hybrid boards composed of green tea and wood fibers, and prediction of static bending strength performances the antibiotic effect using the d–limonene oil extracted to wasted mandarin peels in Cheju. *Journal of the Korean Oil Chemists Society*. **26**: 350–356

Seybert, A. F., D. F. Ross 1977 Experimental determination of acoustic properties using a two–microphone random excitation technique. *J. Acoust. Soc. Am*., **61**: 1362–1370

Suzuki, C., H. Yano and H. Tachibana 1981 A new method of measuring absorption characteristics of acoustic tube normal incident sound materials using acoustic tube. *Journal of the Acoustical Society of Japan* (E)2. **3**:160–167