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An Experimental Study on the Absorption Property of Slit Absorbers with Composite Details

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Abstract

Single absorbing materials and Helmholtz resonators have limited absorption characteristics over limited frequency ranges due to their structures and properties. Porous materials are highly absorptive for mid and high frequency ranges, while they have little sound absorption for low frequency sounds. Helmholtz resonators are generally used to absorb sound energy for a specified frequency range. Hence they have limited capability in controlling the overall acoustic properties of a space. Not much has been known about useful finishing materials which have enough rigidity and absorption over broad frequency range, in spite of wide demands from acoustic designers and consultants. The present work measured and analyzed absorption characteristics of a slit absorber by varying surface materials, depths of air gap, dimensions of slat and slit widths. It was found that the narrower the slit width, the larger the absorptions over the wide frequency ranges and the pattern was dependent on the presence of porous material. Narrower slat's width tend to increase the slit absorber's absorption more or less. Absorption coefficients at low frequency ranges were dramatically improved (from 0.23 to 0.56) by increasing air gap when porous materials were present.

Keywords: *Slit absorbers, Absorption, Architectural acoustics*

I. Introduction

Every material has a sound absorbing capability more or less. Sound absorptive materials, used for finishing surfaces of a room, can be categorized into number of groups which have different sound absorption characteristics, depending on their physical properties and boundary conditions. Both porous and panel type materials selectively absorb either mid and high frequency range or low frequency sounds according to their physical properties and boundary conditions. Helmholtz resonator is usually designed to have absorptive characteristics over particular frequency ranges.

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However, it is almost impossible to carry out a predictable acoustic design of rooms with such a limited list of single absorbing materials. Unfortunately, few researches have been performed to develop absorbing materials with composite details which can be directly applied to the acoustic design of rooms. Sound absorption for low frequency ranges can not be easily achieved while it is easy to control mid and high frequency sounds in spaces for performance and lecture.

The present work ultimately aims at developing useful sound absorbers with composite details whose absorption capabilities are evenly distributed over broadband frequency ranges and easily controllable. In an attempt to achieve the goal, the influence of surface condition, the presence of porous materials, and the size of air gaps on the absorption characteristics of slit absorbers was examined and discussed by measuring absorption coefficients in a reverberation chamber.

II. Slit Absorbers with Composite Details

Finishing materials for the walls in an acoustic space can not be easily chosen since it is generally required for such materials to be rigid enough and meet the acoustic requirements as an important part of interior design. Porous absorbers are generally avoided for finishing the surface of walls as they're quite poor in absorbing low frequency sounds and furthermore lack rigidity[2,3].

Slit absorbers have been known to be highly absorptive for a specific frequency range, which can be found in resonant absorbers[5,6]. The resonance frequency of a slit absorber can be decided using equation (1).

$$f=\frac{c}{2\pi}\sqrt{\frac{P}{L(l+Kb)}} \tag{1}$$

where, c : sound velocity (m/s)

L : the depth of air cavity

l : slat width

P : the ratio of opened area

b : slit width

a : slit depth

K : correction factor ($K=\frac{1}{\pi}+\frac{2}{\pi}\log e\frac{2a}{b}$)

Therefore, the use of wooden slats and slits on the surface of a slit absorber can improve low frequency range sound absorption as well as provide required amount of rigidity and decorative features. Also, it is expected that the absorbing characteristic of a porous material installed behind slits and slats may dominate entire absorptivity of the structure by employing narrower slats. On the other hand, the slit absorber with composite details turns into a composite detail, covered with a perforated panel, by keeping the area of slits less than 20% of the total surface area and shows a bell-shaped absorptivity pattern over a specific frequency, which is generally found in resonance absorbers. However, they mainly absorb low frequency sounds (below 1 kHz) due to the differences in the conditions of openings. In order to get even absorptivity over broad frequency range, it may be necessary to introduce porous materials behind the slits and slats for mid and high frequency ranges and air spaces between the porous material and rigid wall.

III. Experimental Setup

3.1. Measured Structures and Materials

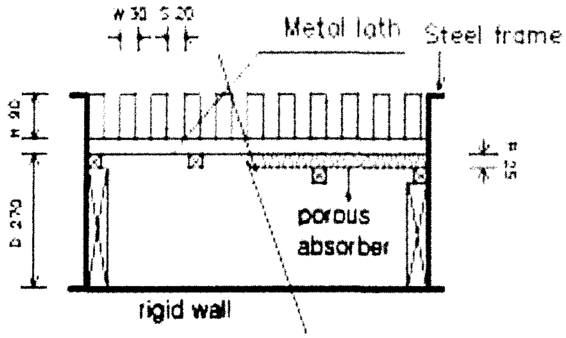
Absorption characteristics of slit absorbers with composite details were measured and analyzed with different configurations for surface conditions and air cavity. Two cases (30 mm and 45 mm) for slat widths and three cases (20, 40, and 57%) for the percentages of slit area relative to the whole surface area were examined. The influence of changing slit width on the overall performance was examined for two slit widths (20 mm and 40 mm). Also, the relationship between the porous material and the slit width were investigated for the slit absorber by varying the details behind the slits (with and without porous materials in an air cavity for the details of 'rigid wall+air cavity+slits and slats' structure). The introduced porous material was 25 mm thick polyester (density 60 kg/m^3) manufactured by S company (Table 1). Finally, the influence of air cavity were examined with three air cavity depths (70, 170, and 270 mm). Figure 1 shows the details

Table 1. Properties of the porous material used in this work.

material	thickness	density	etc
polyester	25mm	60kg/m^3	

Table 2. Configurations of surface conditions (mm).

slat (thickness × width	slit width	depth of air cavity
90 × 30	20, 40	70, 170, 270
90 × 45	〃	〃
30 × 90	〃	〃
45 × 90	〃	〃



D: depth of air cavity H: slat thickness S: slit width
W: slat width P: thickness of a porous material (mm)

Figure 1. Section of a test specimen.

Figure 2. A photograph of a test specimen.

for one of the structures measured in the present work (air cavity depth, 270 mm; slit width, 20 mm; slat width, 30 mm).

3.2. Measurement Setup and Method

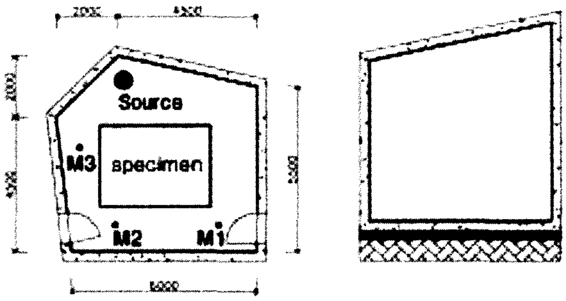
The standardized standing wave apparatus can be used to determine both the normal incidence absorption coefficient and complex impedance of a sample of material placed at the end of the tube. However, the impedance tube method can not consider the absorption of random incidence sounds. Also, it is generally impossible to measure the absorption coefficients of complex absorbing structures with air spaces larger than 100 mm, due to the limited dimension of the tube. Therefore, the absorption coefficients of absorbers, considered in this work were measured in a reverberation chamber which complies with the requirements by Korean Standard (KS F 2805). The whole measurements are carried out strictly following the processes suggested by Korean Standard (KS F 2805[4]). Figure 3 shows the geometrical shapes and dimensions of the reverberation chamber, located at Mokpo National University. Also, the details and reverberation times (empty condition) of the chamber were listed in Table 3 and 4.

Table 3. Details of Mokpo National Univ. reverberation room.

floor plan	irregular pentagon
corss section	irregular trapezoid
floor area	32.75m²
measurement area	9.72m²
volume	209.9m³
ratio of diagonal length	1.56
Surface area	200.9m²

Table 4. Reverberation times of an empty chamber.

Frequency (Hz)	Reverberation time (s)
125	15.91
250	15.57
500	12.52
1000	10.09
2000	7.23
4000	3.89



(a) Floor-plan (b) Section

Figure 3. The geometry and dimensions of the reverberation chamber at Mokpo National Univ.

The test specimen was placed at the center of the floor, whose area measured was 9.72 m^2 (2.7×3.6 m). Three different positions were selected in the reverberation chamber and measurements were repeated 9 times at each position for 1/1 octave band frequencies (125~4000 Hz). Arithmetic mean was obtained from 27 measurements and the absorption coefficient for an absorber was determined using equation (2).

$$\alpha = \frac{55.3V}{cS}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad (2)$$

Table 5. Details of equipments used in this work.

Equipments	Manufacturer	Model
System Analyzer	01 dB	Symphony
Analyzing Software	01 dB	dBbati II
Notebook Computer	Samsung	Sense 650
Microphone	Gras	AP40
Microphone Power Supply	01 dB	Built-in
Microphone Preamplifier	Gras	AF26
Calibrator	B&K	Type 4230
Loudspeaker	Norsonic Boss	Type 229
Power Amplifier	Norsonic Boss	Type 235

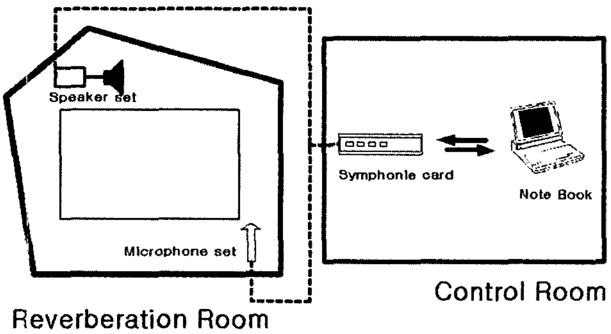


Figure 4. Measurement setup.

where, α : absorption coefficient of a specimen

c : sound velocity

S : surface area of a specimen

T1: reverberation times measured with a specimen

T2: reverberation times measured without a specimen

V : volume of a reverberation chamber

Table 5 lists the details of the equipments used in this experiment and Figure 4 shows the diagram of a measurement setup.

IV. Absorption Coefficients of Slit Absorbers with Different Configurations

4.1. Without a Porous Absorber Within Air Cavity

4.1.1. The Influence of Slat Widths and Depths of Air Space (slit width, 20mm)

The absorption coefficients of a slit absorber was slightly deteriorated by increasing the depth of slat when air cavity

Table 6. Measured absorption coefficients by varying the size of slats and the depth of air cavity (slit width, 20mm)

slat (thickness × width)	depth of air cavity	1/1 octave band frequency (Hz)					
		125	250	500	1K	2K	4K
90mm×30mm (a)	70mm	0.13	0.20	0.34	0.37	0.50	0.54
	170mm	0.19	0.23	0.28	0.38	0.53	0.61
	270mm	0.19	0.23	0.29	0.43	0.56	0.62
90mm×45mm (b)	70mm	0.11	0.18	0.31	0.34	0.47	0.47
	170mm	0.15	0.21	0.24	0.32	0.47	0.54
	270mm	0.18	0.21	0.26	0.37	0.50	0.59
30mm×90mm (c)	70mm	0.09	0.14	0.27	0.30	0.24	0.33
	170mm	0.13	0.18	0.22	0.24	0.30	0.38
	270mm	0.17	0.18	0.21	0.27	0.34	0.43
45mm×90mm (d)	70mm	0.09	0.14	0.29	0.28	0.24	0.33
	170mm	0.14	0.19	0.23	0.24	0.32	0.41
	270mm	0.17	0.19	0.22	0.27	0.34	0.43

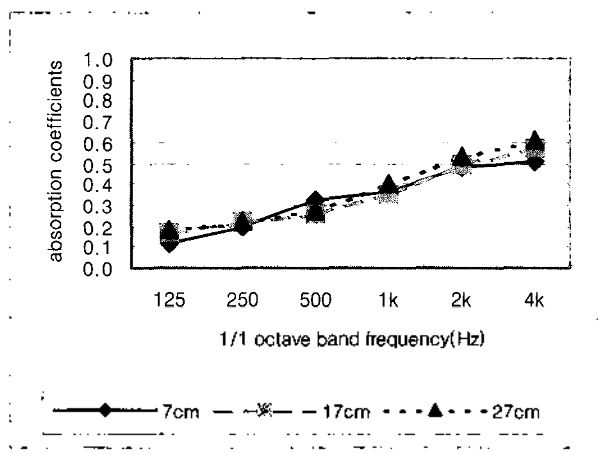


Figure 5. Measured absorption coefficients by varying the depth of air cavity (means for (a) and (b)).

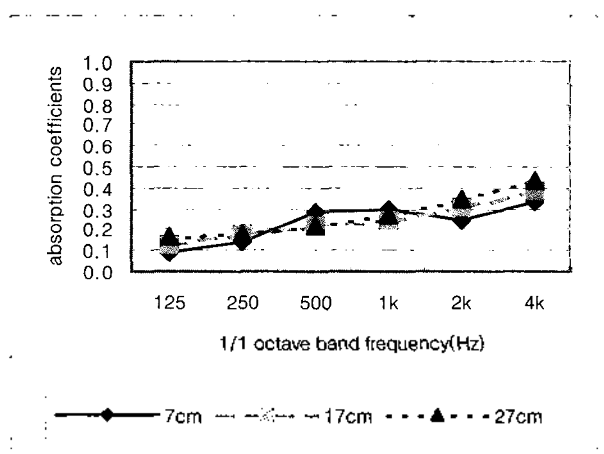


Figure 6. Measured absorption coefficients by varying the depth of air cavity (means for (c) and (d)).

was placed in front of the rigid wall (Table 6). The depth of air cavity did not change the absorption characteristics of a slit absorber. Also, any significant improvement in the absorptivity of a slit absorber was observed when the slat thickness was increased from 30 mm to 45 mm without changing slat width. Figure 5 and 6 shows the measured coefficients of slit absorber by changing the depth of an air cavity, while the widths and thicknesses of slats were kept constant. Changes in the depth of an air cavity slightly improved absorptivity at low- and high-frequency ranges, and resulted in decreases of absorptivity at mid-frequencies.

4.1.2. The Influence of Slat Widths and the Depth of Air Cavity (slit width, 40mm)

When the slit width of 40 mm was applied, quite similar absorption characteristics to those measured with 20 mm slit width were observed, while overall absorption coefficients were slightly decreased. Relatively small absorption coefficients were measured for low frequency ranges, and similar effects were observed for high frequencies (ranged from 0.35 to 0.38 when 70 mm of air cavity was applied). Figure 7 and 8 shows changes in absorption coefficients by increasing the depth of air cavity while the width and thickness of slat were kept constant. As was found for 20 mm of slat width, changes in the depth of air cavity increased absorptivity of low and high frequency sounds, while played a negative role for mid-frequency sounds.

4.2. Installation of a Porous Absorber

4.2.1. Changes in Absorption Coefficient with 20mm Slits

It was expected that the absorption characteristics of the slit absorber might be significantly changed by introducing porous absorbers between the slat and the background wall. Absorption coefficients at mid and high frequency range would be increased by the absorption of porous absorber. Absorption coefficients at high frequency range was also expected to be increased by the presence of air cavity.

Table 8 shows the measured absorption coefficients with

Table 7. Measured absorption coefficients by varying the size of slats and the depth of air cavity (slit width, 40mm)

slat(thickness × width)	depth of air cavity	1/1 octave band frequency (Hz)					
		125	250	500	1K	2K	4K
90mm×30mm (a)	170mm	0.11	0.16	0.25	0.31	0.36	0.38
	170mm	0.16	0.18	0.24	0.33	0.38	0.46
	270mm	0.15	0.19	0.25	0.33	0.38	0.46
90mm×45mm (b)	70mm	0.09	0.14	0.24	0.30	0.34	0.37
	170mm	0.14	0.18	0.23	0.29	0.35	0.43
	270mm	0.15	0.18	0.24	0.31	0.36	0.43
30mm×90mm (c)	70mm	0.09	0.14	0.27	0.30	0.24	0.33
	170mm	0.12	0.16	0.20	0.22	0.29	0.34
	270mm	0.14	0.16	0.19	0.25	0.32	0.40
450mm×90mm (d)	70mm	0.08	0.12	0.23	0.27	0.23	0.27
	170mm	0.13	0.17	0.21	0.23	0.31	0.36
	270mm	0.16	0.17	0.21	0.26	0.32	0.39

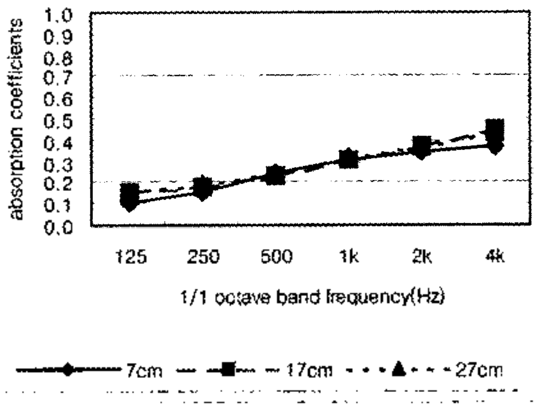


Figure 7. Measured absorption coefficients by varying the depth of air cavity (means for (a) and (b)).

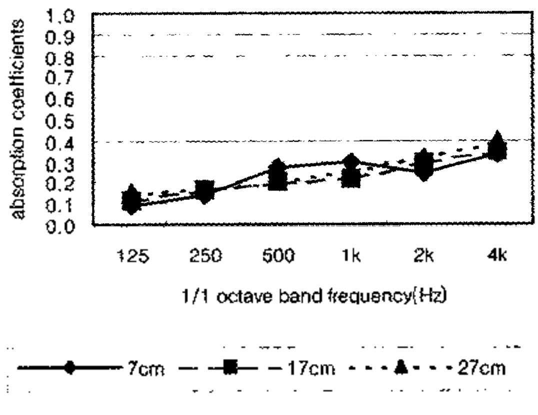


Figure 8. Measured absorption coefficients by varying the depth of air cavity (means for (c) and (d)).

Table 8. Measured Absorption coefficients with changes in the size of slats and the depth of air cavity (slit width, 200mm).

slats (thickness × width)	air cavity	1/1 octave band frequency (Hz)					
		125	250	500	1K	2K	4K
90mm×30mm (a)	70mm	0.24	0.51	0.95	0.76	0.82	0.85
	170mm	0.40	0.74	0.91	0.84	0.88	1.0
	270mm	0.56	0.86	0.92	0.82	0.88	1.0
90mm×45mm (b)	70mm	0.26	0.54	1.06	0.81	0.90	0.93
	170mm	0.40	0.84	0.85	0.76	0.86	0.93
	270mm	0.60	0.85	0.85	0.81	0.87	0.94
30mm×90mm (c)	70mm	0.25	0.58	1.01	0.68	0.58	0.58
	170mm	0.42	0.96	0.90	0.68	0.63	0.65
	270mm	0.68	0.92	0.77	0.72	0.64	0.70
45mm×90mm (d)	70mm	0.24	0.58	1.03	0.64	0.59	0.60
	170mm	0.42	0.97	0.80	0.62	0.63	0.68
	270mm	0.68	0.89	0.72	0.68	0.67	0.72

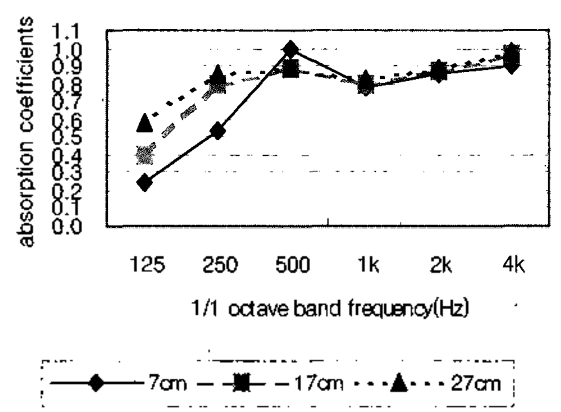


Figure 9. Measured absorption coefficients by varying the depth of air cavity (means for (a) and (b)).

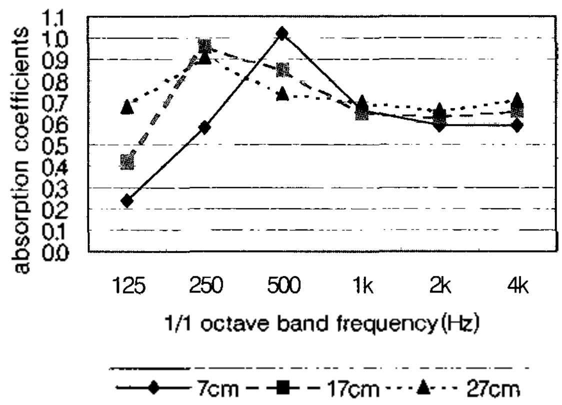


Figure 10. Measured absorption coefficients of wide-and-shallow slats (Means for (c) and (d)).

changes in width and thickness of wood slats and the depth of air cavity. As predicted, absorption coefficients at mid and high frequency ranges above 500 Hz are remarkably increased by installing porous absorbers. Absorption coefficients at 125 Hz and 250 Hz bands are increased according to the dimensions of air cavity. When the widths of slats are wider, 'c' and 'd' cases, the absorption effects of porous absorbers are lessened. This suggests that slit absorbers with wide-and-shallow slats have lower absorptivity at high frequency bands compared to those who have narrower ones.

4.2.2. Changes in Absorption Coefficients with 40mm Slits

The probability of sound incidence coming directly into the slits and hitting the porous absorber is generally increased with the wider slits. Changes in resonance pattern around the wider slits, the increased area of porous absorbers, and probability of being hit by incident sounds as well, are important factors which decide absorption behavior.

Result shows that the absorption coefficient at low frequencies are a little bit lower than those for 20 mm slits. However the absorption coefficients at higher frequencies are getting slightly higher, especially with narrow-and-deep slits.

Table 9. Measured absorption coefficients with changes in the size of slats and the depth of air cavity (slit width, 40mm).

slats (thickness × width)	air cavity	1/1 octave band frequency (Hz)					
		125	250	500	1K	2K	4K
90mm×30mm (a)	7cm	0.23	0.48	0.96	0.84	0.85	0.87
	17cm	0.38	0.72	0.97	0.83	0.84	0.92
	27cm	0.56	0.85	0.97	0.82	0.85	0.97
90mm×45mm (b)	7cm	0.23	0.49	1.0	0.79	0.83	0.82
	17cm	0.39	0.74	0.94	0.82	0.84	0.90
	27cm	0.57	0.86	0.94	0.83	0.85	0.91
30mm×90mm (c)	7cm	0.21	0.51	1.0	0.74	0.61	0.54
	17cm	0.40	0.89	0.96	0.74	0.69	0.66
	27cm	0.67	0.92	0.83	0.78	0.70	0.69
45mm×90mm (d)	7cm	0.23	0.51	1.0	0.75	0.67	0.61
	17cm	0.41	0.87	0.93	0.72	0.70	0.67
	27cm	0.67	0.91	0.83	0.76	0.71	0.70

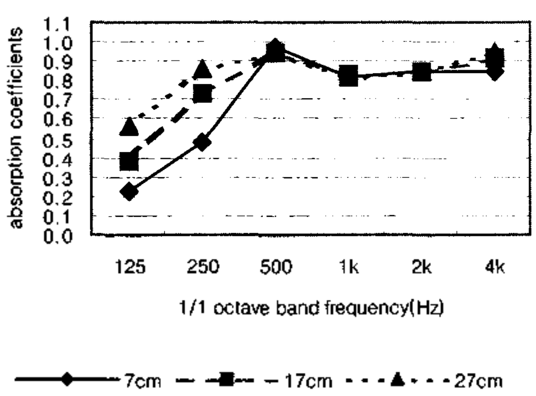


Figure 11. Measured absorption coefficients by varying the depth of air cavity (means for (a) and (b)).

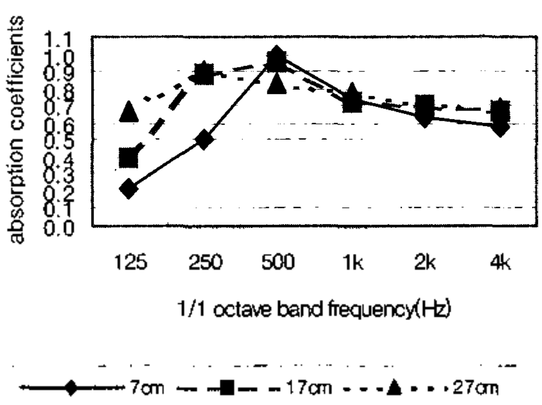


Figure 12. Measured absorption coefficients by varying the depth of air cavity (means for (c) and (d)).

V. Discussion

5.1 Effects of Porous Absorbers

Slit absorbers, consited of slits and slats on a rigid wall with air cavity, are found to be useful for wide band sound absorption[6,7]. But the slats, as well as air cavity, did not provide high absorption for all frequency ranges, as shown in figure 13. Though slit absorbers without porous absorber have a quite good performance in high frequency range, it is hard to treat this as a wide range sound absorber because of its poor performance at low frequency bands.

Insertion of porous materials in the air cavity could be a good alternative to get better absorptions at higher frequencies. Furthermore, the damping effect of porous material within the resonance volume behind the slats seems to an advantage at absorbing low frequency sounds, as well. As shown in table 10, absorption coefficients of a slit absorber using 90 mm (depth) x 30 mm (width) wood slats have been doubled by inserting porous material in the air cavity. When the air cavity is increased up to 270 mm, the absorption coefficient in 125 Hz octave band goes up to 0.56 (see table 8). It is clear that slit absorbers could be a wide band absorber only if supported by the porous material in the air cavity. The effect of porous absorber is to increase the absorption coefficient not only at low frequency range but at higher bands.

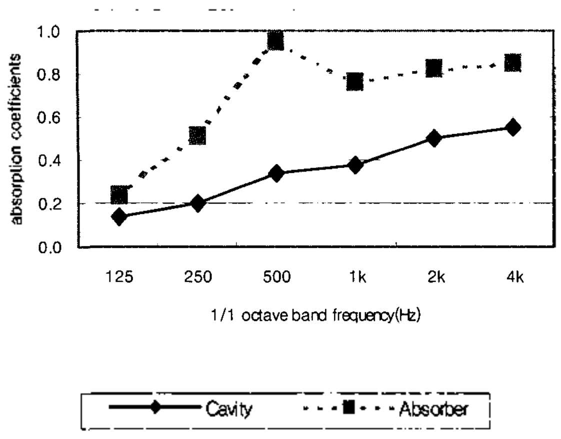


Figure 13. Measured absorption coefficients due to the presence of porous material in the air cavity.

Table 10. Measured absorption coefficients with porous material in the air cavity (air cavity, 70mm).

slats (thickness × width)	porous absorber	1/1 octave band frequency (Hz)					
		125	250	500	1K	2K	4K
90mm×30mm	no	0.13	0.20	0.34	0.37	0.50	0.54
	yes	0.24	0.51	0.95	0.76	0.82	0.85

5.2. Effects of Surface Conditions

5.2.1. Dimension of Slats

Four different slat layouts were considered in this experiment. The effect of wood slats, with different configurations (90×30 mm and 90×45 mm) were examined, where wider side of slat was faced up and vice versa.

When there is no porous absorber behind the slats and the narrow side of slat was faced up, slat width of 30 and 45 mm, the absorption coefficients were found to be slightly increased. It is also observed that wider surface caused more reflections from its solid surface, and accordingly less absorption occurred in the air cavity due to shorter resonator neck. But in the other case, with porous absorber in the air cavity, no significant changes were observed due to the dimension of slats. Porous absorber is supposed to play a dominant role rather than the layouts of slats. Absorption coefficients of slit absorber were gradually increased and had a peak with the slit area, reduced to below 20% of total surface.

5.2.2. Dimension of Slits

Two different slit sizes, 20 mm and 40 mm, were applied to investigate the effets of slit dimension on absorption behavior of a slit absorber. Dimensions smaller than 40 mm seem to be practical solutions for supplementing the limited absorptivity of porous materials inside the slits. Table 11 shows differences in opened (slit) area between the slit size 20 mm and 40 mm.

Result shows that narrower slit case has higher absorption coefficients at all frequency bands for the slit absorber, consisted of slats on solid wall with air cavity and without porous absorber. As presented in table 12 and figure 14, the observed differences in absorption coefficients between those two slit sizes are ranged from 0.04 (at 125 Hz) to 0.18 (at 4 kHz). The differences are noticeable especially at higher bands.Although their absorption coefficients are not that high, the change rates are quite noticeable, ranged from 27% (at 125 Hz) to 39% (at 4 kHz).

But this is not the case when porous absorber was installed in the air cavity. As mentioned before, in section 4.2, installing porous absorber itself has a remarkable effect on the absorption performance of a slit absorber. Also, the slit size was not a major factor affecting the absorption coefficients any more. Table 13 and figure 15 shows the differences in absorption coefficients between the two different slit sizes, for all frequency bands. They are almost negligible. As far as the changing rate is concerned, they are varied from 0% (at 125 Hz) to 3% (at 4 kHz).

Table 11. Percentages of opened area in slit absorbers.

slats (thickness×width)	slit dimension	opened area
90mm×30mm	2cm	40%
	4cm	57%

Table 12. Measured absorption coefficients by varying the size of slit's width.

slats (thickness × width)	slit dimension	1/1 octave band frequency (Hz)					
		125	250	500	1k	2k	4k
90mm×30mm	20mm	0.19	0.23	0.29	0.43	0.56	0.62
	40mm	0.15	0.19	0.25	0.33	0.38	0.46

Table 13. Measured absorption coefficients by varying slit width (air cavity 270mm).

stalts (thickness × width)	slit dimension	1/1 octave band frequenc y(Hz)					
		125	250	500	1k	2k	4k
90mm×30mm	20mm	0.56	0.86	0.92	0.82	0.88	1.0
	40mm	0.56	0.85	0.97	0.82	0.85	0.97

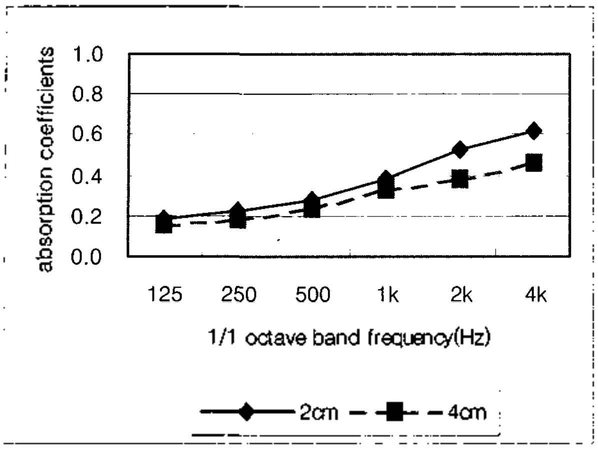


Figure 14. Measured absorption coefficients by varying the slit width (air cavity 270mm, without porous material).

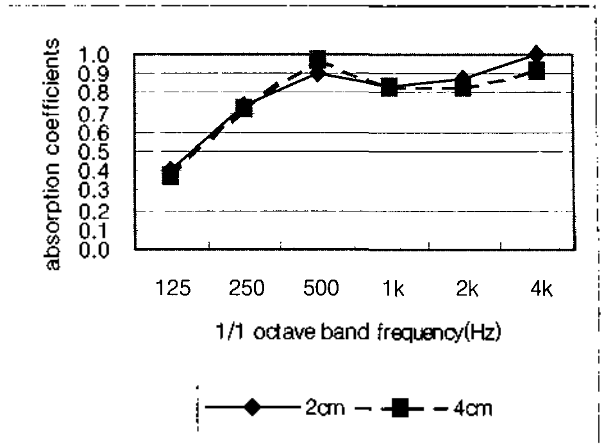


Figure 15. Measured absorption coefficients by varying the size of slit's width (air cavity 270mm) with porous material.

Table 14. Measured absorption coefficients with air cavity (slit width, 20mm).

slats (thickness × width)	air cavity	1/1 octave band frequency (Hz)					
		125	250	500	1K	2K	4K
90mm×30mm	70mm	0.13	0.20	0.34	0.37	0.50	0.54
	170mm	0.19	0.23	0.28	0.38	0.53	0.61
	270mm	0.19	0.23	0.29	0.43	0.56	0.62

Table 15. Measured absorption coefficients by varying the air cavity (slit width 20mm, with porous material).

slats (thickness × width)	air cavity	1/1 octave band frequency (Hz)					
		125	250	500	1K	2K	4K
90mm×30mm	70mm	0.24	0.51	0.95	0.76	0.82	0.85
	170mm	0.40	0.74	0.91	0.84	0.88	1.0
	270mm	0.56	0.86	0.92	0.82	0.88	1.0

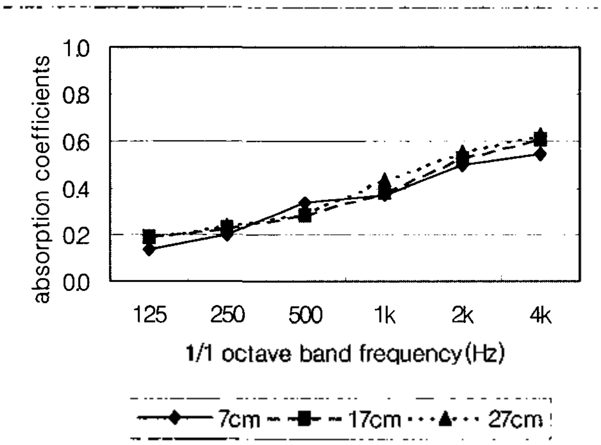


Figure 16. Measured absorption coefficients with air cavity.

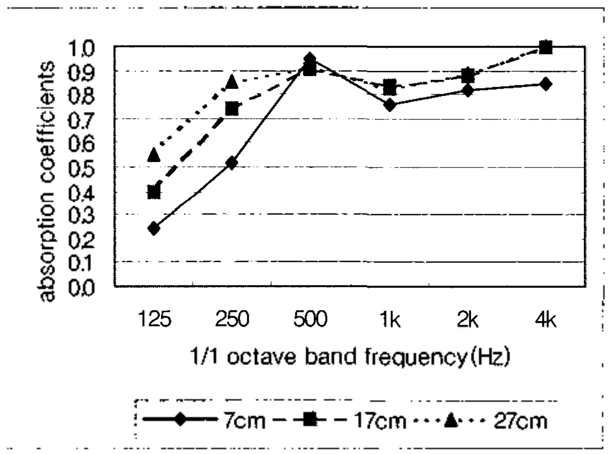


Figure 17. Measured absorption coefficients by varying the air cavity (slit width 20mm, with porous material).

5.3 Effects of Air Cavity

Slit absorbers, consisted of slats on solid wall and air cavity, are supposed to be a sound resonator system. Slit, the space between two slats, and the air cavity behind the slats could be treated as a single resonator. The resonance frequency was calculated using the equation (1). It is assumed that the slit absorber had a peak over a particular frequency range in its absorption coefficient according to the nature of a resonator system. It is not clear in the slit absorber without porous material. As shown in table 14 and figure 16, an up-climbing curve in the frequency domain and a little improvement due to the air volume was observed, and there was no dominating peak.

The nature of a resonator system is more clearly observed in slit absorbers with porous material. There existed a peak in their absorption coefficients as presented in table 15. The peak absorption is to be seen near 500 Hz, and the volume effect is more clearly shown. As plotted in figure 17, low frequency absorption performances were improved from 0.24 to 0.56 at 125 Hz and 0.51 to 0.86 at 250 Hz, by increasing the depth of air cavities. But the behavior of slit absorbers, even with porous material, are not exactly estimated with the resonance system theory. The peak was found at 500 Hz in this experiment, while resonance frequency calculated by the equation (1) was around 300 Hz. It is assumed that the behavior of slit absorber is more complicated than a single resonator system.

VI. Conclusion

Slit absorbers are frequently used in acoustical spaces because of their wide band absorption performance and its rigidity against the possible physical damage. Porous absorbers, surface material and air cavity are the main components of slit absorber which are governing their absorption characteristics.

Slit absorber with porous materials, installed in air cavity, has higher absorption performance than without porous materials. Actually, slit absorber could have wide band absorption characteristics only if supported by the porous material in the air cavity. The effect of porous absorber is to increase the absorption coefficient not only at low frequency range but at higher frequencies.

As for the surface materials, two different results are obtained. Without porous materials, narrow-and-deep slat case has higher absorption coefficients for all frequency bands than the wide-and-shallow slats case. The differences are noticeable especially at higher bands. However, the shape of surface material is not a major factor affecting the absorptivity any more when there are porous materials installed in the air cavity.

Slit absorbers, consisted of slats on solid wall with air cavity, are supposed to be a sound resonator system. But it is not clear for the slit absorber without porous material. As shown in table 14 and figure 16, an up-climbing curve in frequency domain and a little improvement due to the air volume is observed, and no dominating peak was found. There is a peak in their absorption coefficients around the resonance frequency, in the slit absorber with porous material. And low frequency absorption coefficients are improved in porous materials case, as the depth of air cavities are increased.

As a result, porous materials should be installed in the air cavity for effective application of slit absorbers. On condition that the porous materials are installed, controlling the dimension of air cavity is more useful than varying the surface materials and their layout.

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