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NOISE CONTROL FOR A BETTER ENVIRONMENT

Development of natural ventilation devices attached to building envelope to reduce traffic noise

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ABSTRACT

Opening windows has environmental advantages such as bring fresh outdoor air, improving indoor air quality and reducing building cooling energy consumption. But it causes unpleasant feeling for occupants by the influx of noise from outdoors. To solve these problems, it is required the eco-friendly design method of building envelope considering noise reduction and natural ventilation performance. The purpose of this study is to develop a natural ventilation type noise reduction device applicable to the building envelope of apartment buildings. Two natural ventilated prototypes, plenum type and louver type, were designed for similar ventilation performance when 15 % opened window situation. Noise reduction performance of these prototypes was measured by SRI(Sound reduction index) in a laboratory base on the ISO standards. The results of this study are that the plenum type is more effective than louver type for noise reduction from outdoors.

Keywords: Natural ventilators, Sound reduction index, Plenum, Louver
I-INCE Classification of Subject Number: 51

1. INTRODUCTION

Recently, due to land shortage for construction of residential buildings in major cities of Asia countries, such as the South Korea and Japan, the residential apartments have been built next to road facilities[1]. Furthermore, the number of the road facilities such as high volume road and highway have increased with a rapid increase in the use of motor vehicles. Both matters make residents of the residential buildings exposed to incoming traffic noise through a natural ventilation during summer season, and feeling discomfort[2-3]. The idealistic solution is to improve air-tightness of the building by installing the

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external sound insulation system, resulting in preventing incoming noise from outside[4-5]. However, for indoor ventilating, this system requires a mechanical ventilation system. The mechanical ventilation system is not cost-effective due to it consumes energy and requires maintenance[6]. Therefore, an acoustic performance of noise-reduced natural ventilation systems for the apartment buildings is demanded. However, contradictorily, the existing natural ventilation system allows the outside noise into the building. For this reason, there is few system to perform those functions simultaneously. The mutual performance of those functions from the few system is not even evaluated yet.

The study aims to develop an acoustic performance based noise-reduced natural ventilation system as the external apartment building material and evaluate the mutual performance of those functions. The acoustical performance of each system was evaluated in terms of a sound reduction index based on a sound insulation of air-borne sound in accordance with ISO 10140-2.

2. DESIGN AND MANUFACTURE OF VENTILATORS

From literature review on the natural ventilating noise reduction system as the building exterior material, there are four types of ventilation system: (1) a protruding type, (2) a resonance type, (3) a balcony type, and (4) a window mounting type[7-12]. Among these types of it, the window-mounted ventilation system was chosen with considerations of low construction cost, small change of building facade, and small size dimension of the ventilation system comparing to the whole building elevation. For the natural ventilating noise reduction system, a plenum type and a louver type were determined. The plenum type is the most effective system to reduce noise and the louver type is well known one to be used for indoor and outdoor environments. Prototypes of them were manufactured and placed on the bottom of the balcony window.

2.1 Design of ventilators

In the case of the plenum type ventilation noise reduction system, the inlet and outlet have different angles as shown in Fig. 1.The inlet and outlet are made to be staggered, and the opening and closing is made possible according to the user's convenience. A dimension of the system is the length, height, and width of 837 mm, 317 mm, and 84 mm, respectively. A thickness of an aluminium blade is 5 mm. A dimension of the vent cover is the length and width of 750 mm and 30 mm, respectively.

A dimension of the louver type ventilation system is identical to one of the plenum type system. The amount of air-flow can be controlled by adjusting an angle of the six blades installed inside the louver type ventilation system, as shown in Fig. 2.

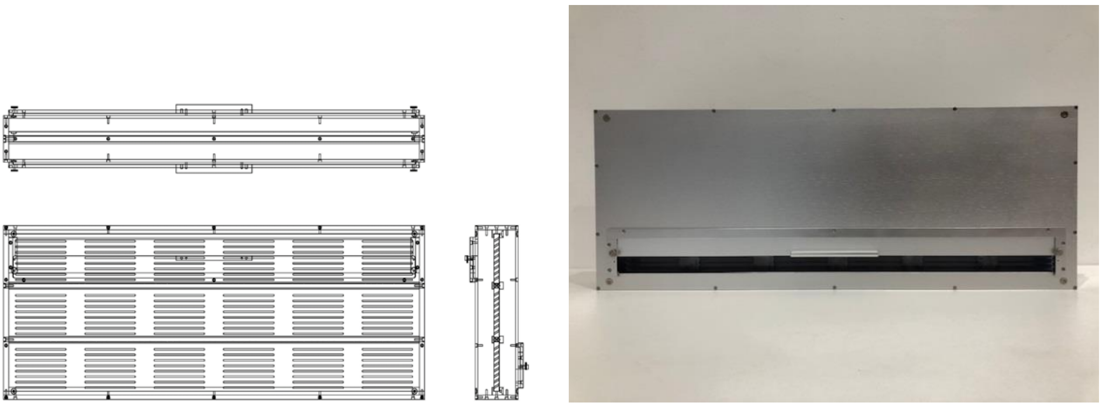

Figure 1. *Drawing and photograph of the plenum ventilator*

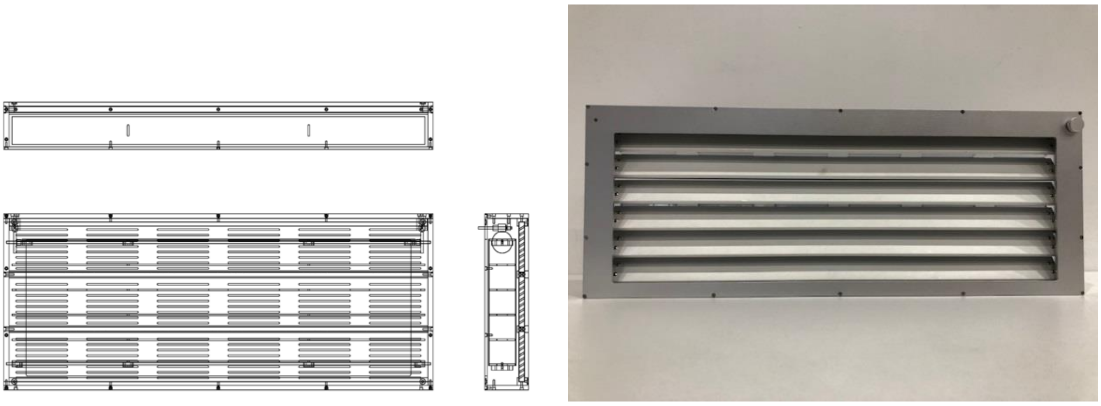

Figure 2. *Drawing and photograph of the louver ventilator*

2.2 Design factors of ventilators

The design parameters of the ventilation system are largely determined by the application of openings, sound absorbing materials, and perforated panels.

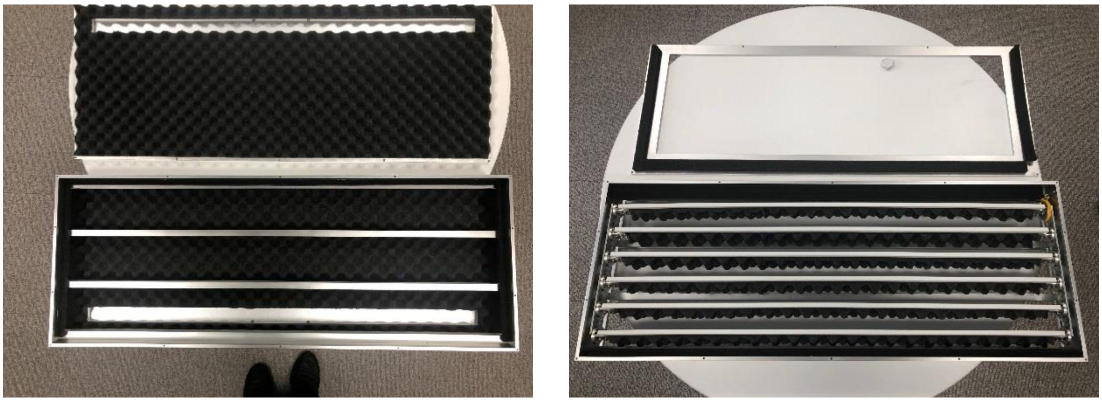

Figure 3. *Absorbing material is applied inside the ventilator (Left: Plenum, Right: Louver)*

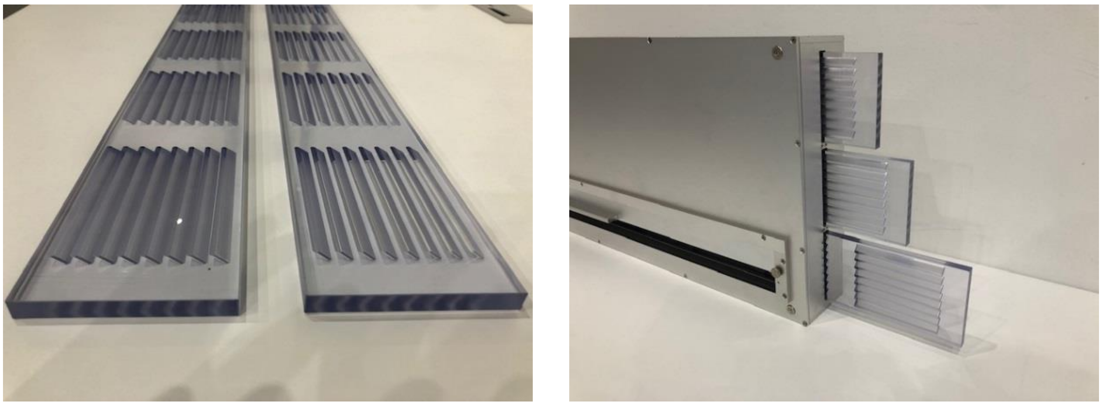

Figure 4. *Application of Micro perforated panel to ventilator*

As shown in Fig. 3., a concavo-convex shaped sound absorbing polyurethane material with 20 mm of thickness was applied. Fig. 4. shows a perforated panel which is with acrylic plate slits. A dimension of the single slit is the length, height, and thickness of 100 mm, 10 mm, and 3 mm, respectively. An angle of the slit cover is 45 degree. Both the plenum and louver ventilation system have three slots of them to put into the perforated panels.

Experimental variables are given in Table 1. A total of 12 cases were tested for evaluating the sound insulation performance. In the tests for the plenum ventilation system, two types of the vent cover variables: opening or closing, three amount of the sound absorbing material usages (0%, 50%, and 100%), and the amount of intake air by the perforated panel (0%, 100%) were considered.

A total of 16 louver ventilation system cases were tested depending on the amount usages of the sound insulation material (0% and 100%) and the amount of intake air (0% and 100%). For the louver system cases, the angles (0°- opened, 30°, 60°, 80°- closed) of the vent cover were considered.

Table 1. *Test Variables*

Ventilator design	Case	Configurations		
		Opening	Absorber linings	Perforated panels
Plenum ventilator	P01	Closed	Full applied	Applied
	P02	Opened		
	P03	Closed	Half applied	
	P04	Opened		
	P05	Closed	Unapplied	
	P06	Opened		
	P07	Closed	Full applied	Unapplied
	P08	Opened		
	P09	Closed	Half applied	
	P10	Opened		
	P11	Closed	Unapplied	
	P12	Opened		
Louver ventilator	L01	0°	Full applied	Applied
	L02	30°		
	L03	60°		
	L04	80°		
	L05	0°	Unapplied	
	L06	30°		
	L07	60°		
	L08	80°		
	L09	0°	Full applied	Unapplied
	L10	30°		
	L11	60°		
	L12	80°		
	L13	0°	Unapplied	
	L14	30°		
	L15	60°		
	L16	80°		

3. METHODOLOGY

3.1 Detail of Laboratory facility design and performance

Sound pressure levels throughout the natural ventilation window were measured by using a two-room sound-transmission facility in accordance with ISO 10140-1[13]. The two-room sound-transmission facility composes of a diffuse-field source room, a test specimen (a ventilation system for this study), and a receiving room as shown in Fig. 5. In the diffuse-field source room and the receiving room, microphones are placed to measure the sound pressure levels in shown arrangement of Fig. 6.

Figure 5. *Sound transmission facility (Left: Outside, Right: Inside)*

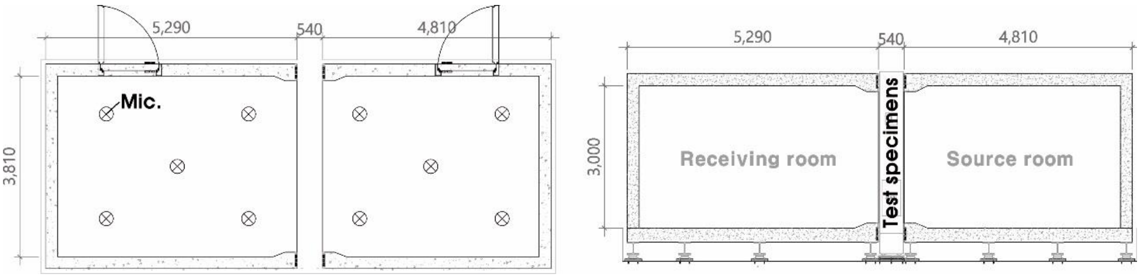

Figure 6. *Configuration of test room (Left: Floor plan, Right: Vertical section)*

3.2 Measurement methods

Acoustical performance is evaluated in terms of a sound reduction index ($\underline{R}$) by according to the ISO 10140-2:2010[14] in the two-room sound-transmission facility. The sound reduction index is converted from a frequency varying transmission loss of the acoustical performance of the ventilator. The sound reduction index (R) is expressed in Eq. 1.

$$R = L_1 - L_2 + 10\,log\left(\frac{S}{A}\right) \quad (1)$$

In which, L_1 and L_2 are reverberant sound-pressure levels in the source room and receiver room, respectively, S is a ventilator area and A is an equivalent sound absorption area in the receiving room. The equipment used for the experiment is given in Table 2.

Table 2. *Test Equipment*

Equipment	Model	Brand
Signal Analyzer	SA-02	RION
Microphone	Type 146AE	GRAS
Speaker #1(Source room)	SRX 835P	JBL
Speaker #2(Receiving room)	Dodecahedron Source: OMNI 5”	NTEX

3.3 Evaluation index

A sound insulation performance of the specimens was evaluated by the weighted sound reduction index (R_w) which is a single number quantity[15]. In addition, the insertion loss (IL) was calculated to evaluate the noise reduction performance for each design case. In the experiment, the design case showing the lowest noise reduction effect was considered as a control and the insertion loss for each design case was calculated.

4. RESULTS

4.1 Plenum ventilator

Table 3 shows sound insulation performance values for each case of the plenum device. The reference value for the insertion loss calculation is the case: P12. Then, the insertion loss was calculated with for each R_w value.

Table 1. *Performance measures for the plenum ventilator.*

Case	Configurations			Rw	C	Ctr	IL
	Opening	Absorber	M.P.P.				
P01	C	F	A	34	-1	-3	10
P02	O	F	A	29	-1	-3	5
P03	C	H	A	33	-1	-3	9
P04	O	H	A	28	-1	-3	4
P05	C	U	A	33	-1	-4	9
P06	O	U	A	25	0	-2	1
P07	C	F	U	34	-1	-4	10
P08	O	F	U	27	-1	-2	3
P09	C	H	U	33	-1	-3	9
P10	O	H	U	26	0	-2	2
P11	C	U	U	32	-1	-3	8
P12	O	U	U	24	0	-2	0

※ O: Opened, C: Closed, F: Full applied, H: Half applied, U: Unapplied, A: Applied.

4.1.1 The vent cover: opening or closing

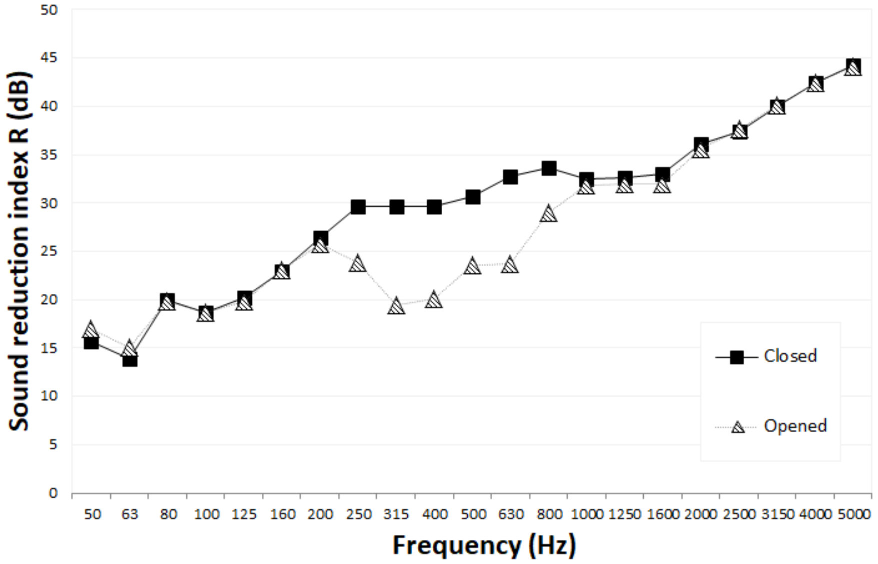

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Figure 8. *Measured third-octave transmission loss(TL) of the plenum ventilator according to opened/closed of the opening(case: P01, P02)*

Under the same conditions of dependence of sound absorbing material and perforated plate, the difference of R_w was 5 ~ 8dB according to opening and closing of openings, and SRI reduction generally occurs in the band of 200 to 1000 Hz. The opening and closing characteristics of the opening are as follows. When the values of each case are compared, the difference of R_w is 0-2 dB in the closed state, and the difference of R_w is 1-5 dB when the opening is opened. This is considered to be a change in the influence of the sound absorption material and micro perforated panel applied inside.

4.1.2 Application of sound absorbing material

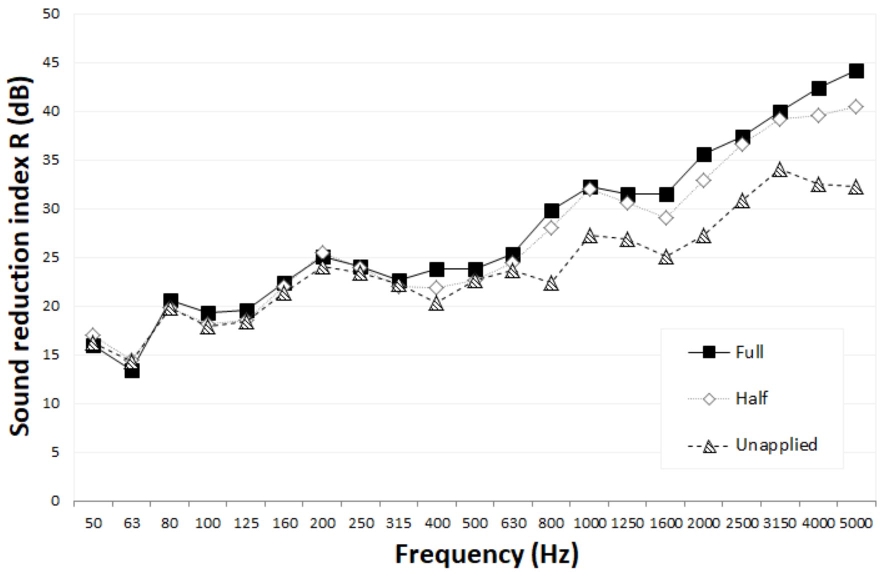

Figure 9. *Measured third-octave transmission loss (TL) of plenum ventilator according to application method of sound absorbing material (case: P02, P04, P06)*

The application method of the sound absorbing material was applied in three ways as the whole, half, and none. As a result of comparing the values of each single value, the difference was 1dB when applying only half of the total application, and 1dB to 4dB when not applied. Fig. 9. shows the SRI value of the sound absorbing material when the opening is open. Noise reduction occurs in the band above 800Hz. As a result of the noise reduction performance evaluation, the application of the sound absorbing material is not greatly different between the whole application and the half application, but the ventilation performance will be greatly different, and it should be considered in the future optimization.

4.1.3 Application of micro perforated panel

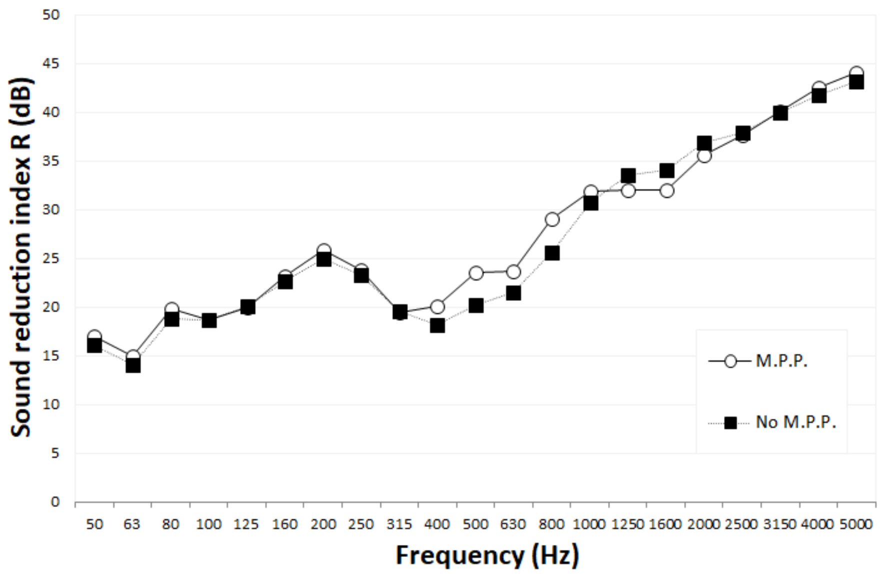

Figure 10. *Measured third-octave transmission loss(TL) of plenum ventilator according to application method of Micro Perforated panel(case:P02, P08)*

With the plenum device assuming a ventilation situation open, 1-2 dB noise reduction effect appears. The SRI difference by M.P.P. is at 200Hz-1000Hz but the effect is negligible.

4.2 Louver ventilator

Table 4 shows sound insulation performance values for each case of the louver device. The reference value for the insertion loss calculation is the case: L13. Then, the insertion loss was calculated with for each R_w value.

Table 2. *Performance measures for the louver ventilator.*

Case	R_w	C	C_{tr}	IL
L01-L03	21	0	-2	3
L04	23	-1	-2	5
L05-L07	20	0	-1	2
L08	21	-1	-2	3
L09-L11	19	0	-1	1
L12	22	0	-2	4
L13-L15	18	0	-1	0
L16	20	0	-1	2

4.2.1 Opening angle of Louver

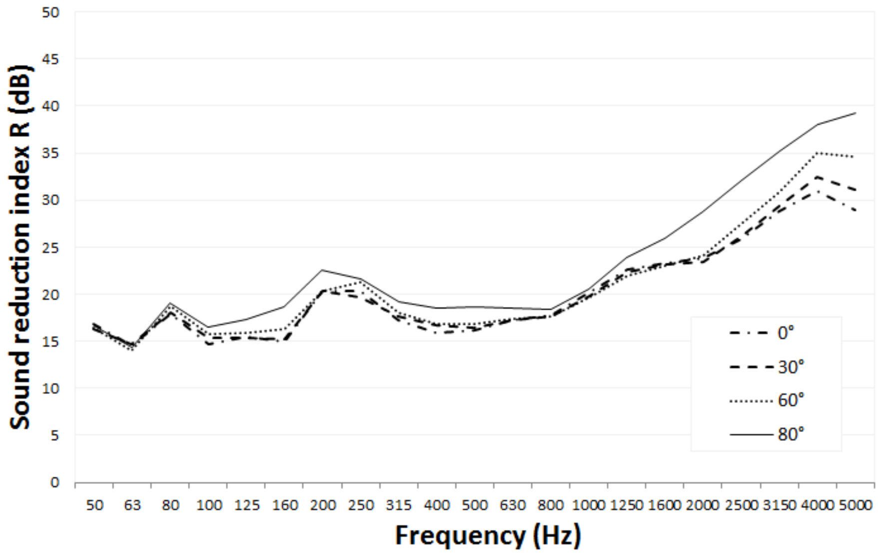

Figure 11. *Measured third-octave transmission loss (TL) of the louver ventilator according to opening angle of the louver ventilator (case: L01- L04)*

The opening angle of the louver blades was set to 0, 30, 60 and 80 degrees. Fig. 11. shows the SRI according to the opening angle when applying sound absorbing material and perforated panel. The same single number quantity was obtained for the angle of the louver from 0 ° to 60 °. The change in frequency band showed a slight difference in the frequency band above 2000Hz. When the opening is closed at 80 °, the sound insulation performance of 2dB is improved, and the frequency band difference is from 100Hz to 5000Hz. When the sound absorbing material and the perforated panel are applied in the same manner, they all have a similar pattern, and the angle in the open state does not greatly affect the sound insulating performance.

4.2.2 Application of sound absorbing material

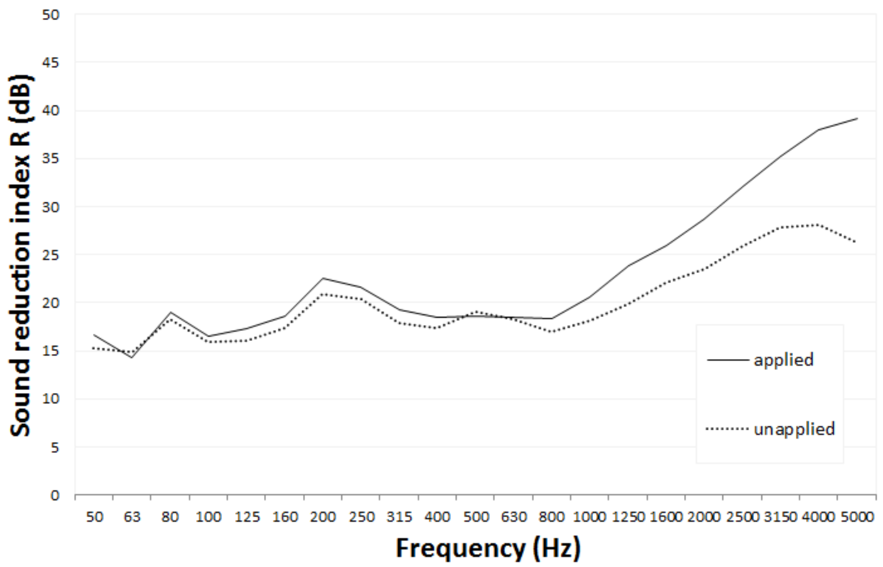

Figure 12. *Measured third-octave transmission loss (TL) of louver ventilator according to application method of sound absorbing material (case:L04, L08)*

The difference between the louver type and the sound absorbing material was similar to that of the plenum, and the sound insulation performance increased as the frequency band was increased above 1000Hz. The comparison of single number quantity values showed 1-2 dB (0 ° - 60 °: 1 dB, 80 °: 2 dB) difference.

4.2.3 Application of micro perforated panel

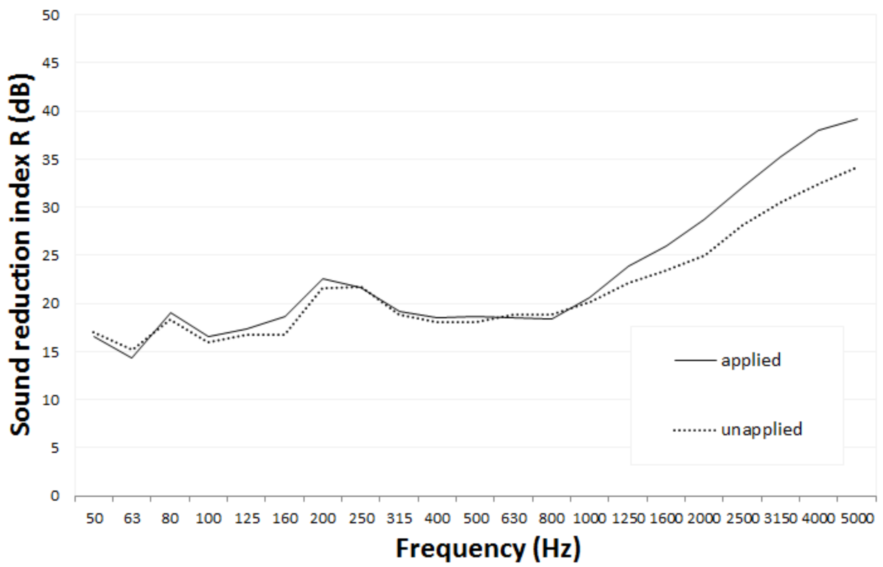

Figure 13. *Measured third-octave transmission loss (TL) of louver ventilator according to application method of Micro Perforated panel(case:L04, L12)*

As a result of analysing the frequency band, in louver type unlike the plenum type, the sound insulation performance was increased in the high frequency band rather than the middle frequency band. The comparison result of a single number quantity to which perforated panels was applied showed a difference of 1-2 dB (0 ° - 60 °: 2 dB, 80 °: 1 dB). This shows that the sound insulation performance of the perforated panel is improved due to the sound absorption effect of the perforated panel when the opening is relatively large.

4.3 Acoustical benefits

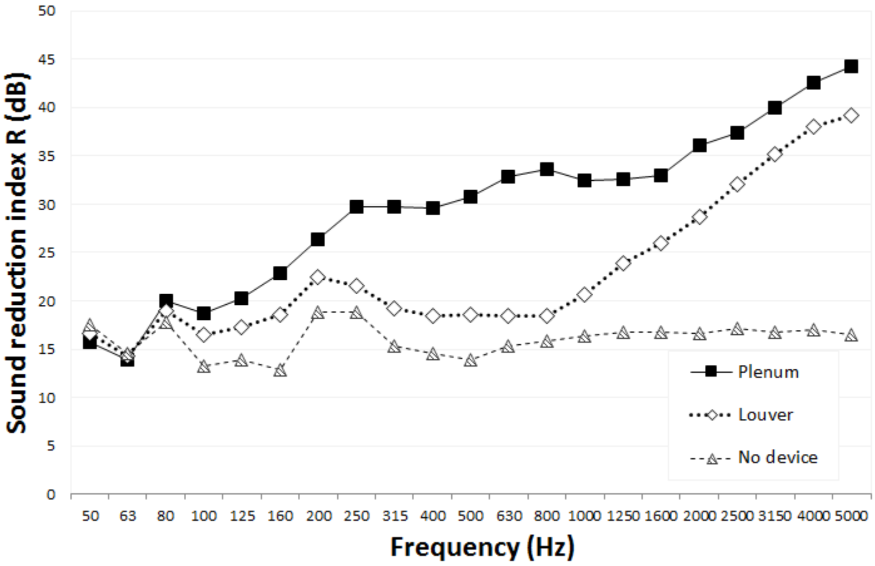

Figure 14. *Comparison of sound insulation performance by each device (case: P01 ,L04)*

Fig. 14. compares the sound insulation performance values of two ventilators and absent. When converted to R_w value, plenum device has the highest sound insulation performance of 34dB, louver 23dB, and no device 16dB respectively. As a result of analysing the sound insulation characteristics by the frequency band of the plenum device, the sound insulation performance is shown from the 80 Hz band, and the sound insulation performance is increased as the frequency band is increased. In the case of the louver type compared with the no device, it shows a constant sound insulation performance of about 4dB from 80Hz to 800Hz, and the sound insulation performance is increased in a band of 1000Hz or more.

5. CONCLUSIONS

Laboratory measurements was conducted on the acoustic performance of noise-reduced natural ventilation systems applied to apartment buildings. The test was carried out to measure sound insulation of air-borne sound according to ISO 10140-2 standard. The natural ventilation devices measured in the tests are plenum type and louver type. Assuming natural ventilation (openings are opened), the noise reduction performance change of each device by design variables showed the improvement of sound insulation performance up to 5dB. In the case of the plenum type, the difference in the sound insulation performance between the opening and closing of the opening was the largest, and the influence of the sound absorbing material and the perforated panel was relatively low. The louver type improved the acoustical performance by 3 dB when the sound absorbing material and the perforated panel were both applied, and the influence by the opening was low. The effect of the perforated panel is increased as the aperture area is increased. As a result of evaluating the sound insulation performance of each device, plenum type showed relatively high sound insulation performance. However, this seems to be caused by a relatively small opening area, and the influence of ventilation will be investigated in the future and comprehensive performance evaluation will be carried out.

6. ACKNOWLEDGEMENTS

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