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IMPROVEMENT OF SOUND INSULATION PERFORMANCE OF WALLS, WINDOWS AND DOORS

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Flanking transmission in apartments occurs through various routes in not only structures including walls, columns, and beams but also windows, doors, and gaps between joints. In particular, aged apartments are vulnerable to external noise through windows or doors due to the corridor access structure and increase in possible gaps. Thus, this study aims to verify the change in sound insulation performance by applying an improved method of sound insulation in walls between households, front doors, and external windows, which are vulnerable to flanking transmission. This study conducted experiments by blocking gaps or improving sound insulation. The improved method of sound insulation was applied to each portion and the results were 19 dB for walls between households, 15 dB for the front door, and 5 dB for the external window, verifying improved sound insulation performance.

Keywords: Improvement of sound insulation performance, Wall between households, Front door, External window, Attachable Door

1. Introduction

Households in apartments share their floors and walls with neighbors so living noise is easily transmitted. Not only structure borne sound generated due to children's jumping but also airborne sounds such as television and voice can be a problem. Such flanking transmission can occur through various routes such as structures including walls, columns, and beams as well as windows, doors, and gaps between joints. In particular, aged apartments are vulnerable to external noise from gaps due to wear of parts such as doors and windows. Furthermore, apartments with corridor access structure, which can be found in aged apartments often, are vulnerable to sound leaks from front doors and windows and external noise through the corridor. Thus, the present study aims to determine the reduction performance of airborne sound by applying the improved method of sound insulation performance targeting boundary walls between households, front doors, and windows, which are the most vulnerable areas of flanking transmission in apartments. The experiments were conducted at a real aged apartment field and a simulation laboratory of an apartment. The boundary wall between walls was reinforced using glass wool and plaster board, and sealant was applied to the front door or windows to tighten the gap. Furthermore, an attachable door was developed and applied to improve sound insulation performance and air-tightness performance.

2. Overview of the measurement

2.1 Measurement place

2.1.1 Field measurement

The sound insulation performance was verified after applying the improved method of sound insulation performance to the boundary wall between households and the front door in the aged apartment. The measured apartment was an aged apartment that was more than 30 years old. It was currently prepared for reconstruction work. The applied target wall was one between master bedrooms of adjacent neighbors (55m2 floor area). The basic wall structure was cement brick 1.0B laying (190 mm) + plaster board, and its thickness was 220 mm approximately and the area of the wall was 3,300 x 2,300 mm.

2.1.2 Laboratory measurement

The measurement laboratory was constructed as similar to a typical apartment structure in Korea. The improved method of sound insulation performance was applied to the front door and external windows in the household whose floor area was 84 m2 and the sound reduction performance was verified. The size of the applied front door was 930 x 2,130 x 38 mm. It was a steel door whose inside was filled with a honeycomb core. The size of the external window was 2,200 x 3,300 mm. It was a single window made of plastic (PVC).

2.2 Measurement and evaluation methods

2.2.1 Measurement method

The measurement and analysis were conducted in accordance with ISO 16283-1 [9] and ISO 16283-3 [10]. The airborne sound insulation performance was evaluated using a different measurement method in the field and laboratory. The different measurement method and evaluation index were applied to the measured areas [8]. For the external window, element and global methods were employed to measure the sound insulation performance. Table 1 shows the measurement method and evaluation index for each area.

Table 1: Measurement method and evaluation index for each area with regard to airborne sound insulation performance

Applied place	Measurement method	Target area	Evaluation index
Field	ISO 16283-1	wall between households	D_w
Laboratory	ISO 16283-3	front door	$R'_{45°,w}$
		external window	$R'_{45°,w}$ (element method)
			$D_{ls,2m,nT,w}$ (global method)

3. Measure of improvements on sound insulation performance

3.1 Wall between households

A boundary wall between households in apartments can be made of steel concrete, steel and reinforced concrete, plain concrete, concrete block, brick or stone masonry. Flanking transmission between boundary walls of neighbors can be noise transmitted directly from the wall, noise delivered through the slab, and/or noise from the ceiling. The present study aims to improve sound insulation performance by reducing transmission sounds. The basic structure of the boundary wall in the measurement was masonry wall [cement brick (190 x 90 x 57) 1.0B laying]. A case for each application was constructed and each sound insulation performance was verified [5]. Wooden stud, plaster board, and glass wool were used, and putty and silicone were used in wall construction, which are generally used such as to minimize the gap [6]. The wall construction details are presented in Table 2.

Table 2: Construction of wall between households

Case	Construction of wall			
	Source room	Masonry wall	Receiver room	Thickness (mm)
Masonry wall	-	Cement brick 1.0B laying	-	190
Case 1	-		plaster board point bonding	205
Case 2 (Original)	plaster board point bonding		plaster board point bonding	220
Case 3	wooden stud + glass wool + plaster board + putty and silicon sealing		-	250
Case 4	wooden stud + glass wool + plaster board + putty and silicon sealing		wooden stud + glass wool + plaster board	310
Case 5	Wooden stud + Glass wool + Plaster board + Putty and silicon sealing		wooden stud + glass wool + plaster board + putty and silicon sealing	310

* Dimension of cement brick: 190*90*57 mm
* Dimension of wooden stud: 50*38 mm (gap: @450)
* Thickness of glass wool: 50 mm
* Thickness of plaster board: 9.5 mm (5 mm-thick plaster board)

3.2 Front door

3.2.1 Sealant

Since the sound insulation performance of members can be affected by round or slit type gaps[2] [3] [4]; gaps should be filled to improve sound insulation performance of the door. The target doors were the front doors in the laboratory. The materials used were polyurethane foam tape and sealant, which can be purchased commercially. Foam tape (Type 3) was attached to all four sides of the door frame tightly and a door sweep (Type 4) was attached to the inside of the door at three sides except for a side of hinge. The applied sealants are presented in Table 3 (c) and (d).

3.2.2 *Attachable Door*

An attachable door was developed to improve sound insulation performance and block the flanking transmission due to gaps by attaching it to the aged front doors. The door can be attached and detached to/from the inside of the existing door easily using a magnet without replacing the existing door. The attachable door was devised to increase strength, sound insulation performance, and air-tightness of the door. It also considered all frequency bands that affected sound insulation performance. It was manufactured with two units to facilitate attachment and detachment. It can be attached without a connecting member or an attachment material using a magnet. A sealant was installed directly to the attachable door to prevent gaps at places where the sides of the attachable door and the door frames were in contact. A screw where the magnet was attached was designed to be embedded to the attachable door so that no gaps were found between existing and the attachable doors. Two types of the attachable door were developed. The exterior finish was the same but internal structure and thickness were different according to whether an anti-vibration pad was present. Table 4 and Figure 1 present the type and structure of the attachable door.

3.3 External window

A gap filling material was used in the external windows of the balcony in the apartment laboratory. The applied materials were polyurethane foam tape, Mohair Bruch seal, and a PVC wind block plate, which were sealants that were all available in the market as gap filling material for windows. Polyurethane Foam tape (Type 1) and mohair brush seal (Type 2) were attached to the rail in the window to minimize a gap between window and window frame. A PVC wind block plate (Type 5) was attached to the bottom place where two windows are interfaced to each other to block gaps. Table 3(a), (b), and (e) present the applied sealants.

Table 3: Types of the applied sealant

	(a) Type 1	(b) Type 2	(c) Type 3	(d) Type 4	(e) Type 5
Material	polyurethane foam tape Ⅰ	mohair brush seal	polyurethane foam tape Ⅱ	door sweep (rigid PVC)	PVC wind block plate
Size	Thickness: 9.5 mm Width: 13 mm	Thickness: 11 mm Width: 20 mm	Thickness: 9 mm Width: 30 mm	Width: 37 mm	Width: 40 mm Height: 90 mm

Table 4: Construction of attachable door

Type	Item	Thickness (mm)
Attachable Door Ⅰ	GI + Polyester 27 mm + GI + Neodium + gap sealant	29
Attachable Door Ⅱ	GI + Polyester 12 mm + Anti-vibration pad + GI + Neodium + gap sealant	28

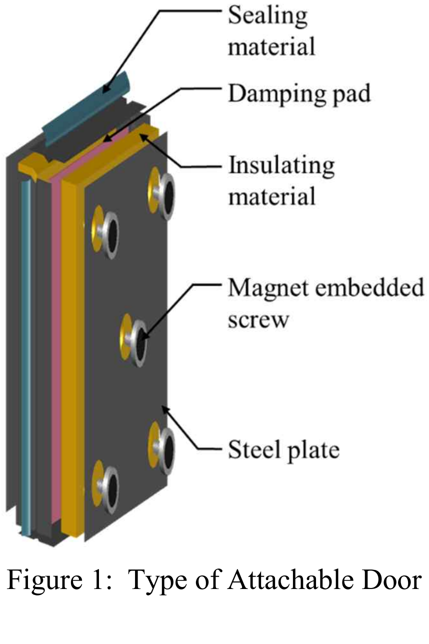
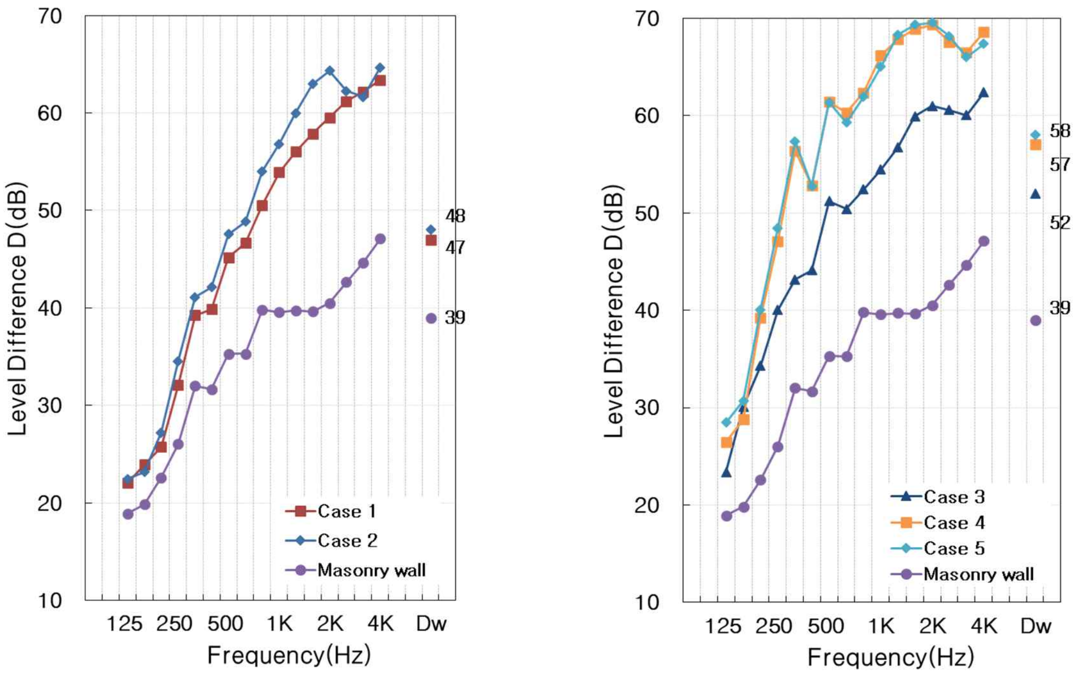


Figure 1: Type of Attachable Door

4. Evaluation and discussion of sound insulation performance

4.1 Wall between households

Figure 2(a) shows the results of changes in sound insulation performance of the boundary wall between households according to the attachment of plaster board, and Figure 2(b) shows the results of changes in sound insulation performance according to the construction of glass wool + plaster board.



(a) Plaster board construction (b) Glass wool + Plaster board construction

Figure 2: Changes in sound insulation performance according to the improved method of airborne sound insulation performance

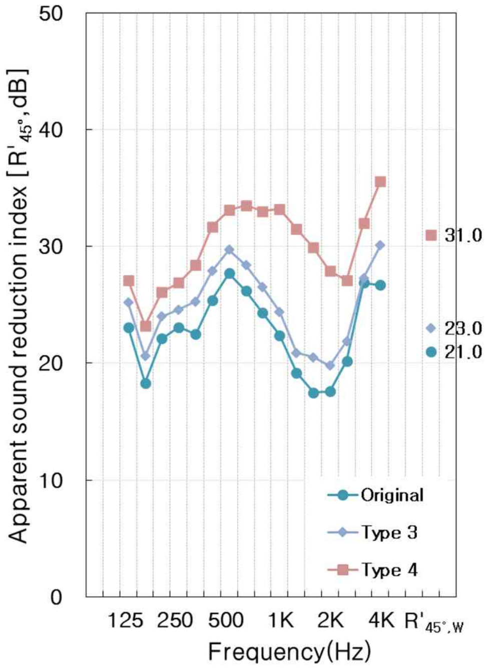
As shown in Figure 2(a), a difference in weighted sound pressure level (D_w) between rooms of the masonry wall was 39 dB, and Case 1 where plaster board was attached on one side of the wall increased sound insulation performance by 8 dB compared to that of the masonry wall. Furthermore, Case 2 where plaster board was attached to both of the walls increased sound insulation performance by 9 dB compared to that of general masonry wall without plaster board and it improved performance by 1 dB compared to that of Case 1.

As shown in Figure 2(b), a difference in weighted sound pressure level (D_w) between rooms in Case 3 was 52 dB. If the same construction was applied to the other wall (Case 4), it improved sound insulation performance by 5 dB. Furthermore, Case 5, in which putty and silicone were added to the wall in Case 4, it improved sound insulation performance by 1 dB than that of Case 4.

Thus, the construction method of plaster board on one side of general masonry wall improved sound insulation performance by 8 dB. When plaster board was applied to two sides, it improved sound insulation performance by only 1 dB, which revealed no significant improvement. Moreover, construction of wooden stud + glass wool + plaster board + putty at two sides of general masonry wall improved sound insulation by 6 dB approximately than that of one side construction. Putty and silicone sealing as finish materials improved sound insulation performance only by 1 dB, which was not significant. It is possible to improve sound insulation performance by 19 dB compared to that of a masonry wall when wooden stud + glass wool + plaster board + putty was applied to two sides.

4.2 Front door

Figure 3 shows the sound insulation performance by frequency when different sealant was applied, and Figure 4 shows the sound insulation performance by frequency when an attachable door was attached.



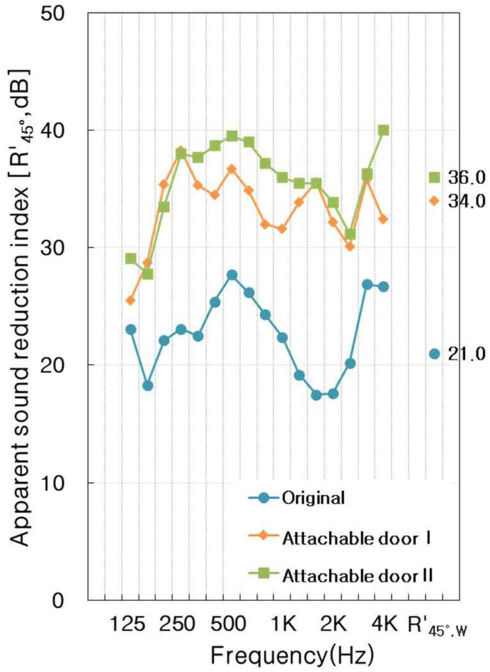


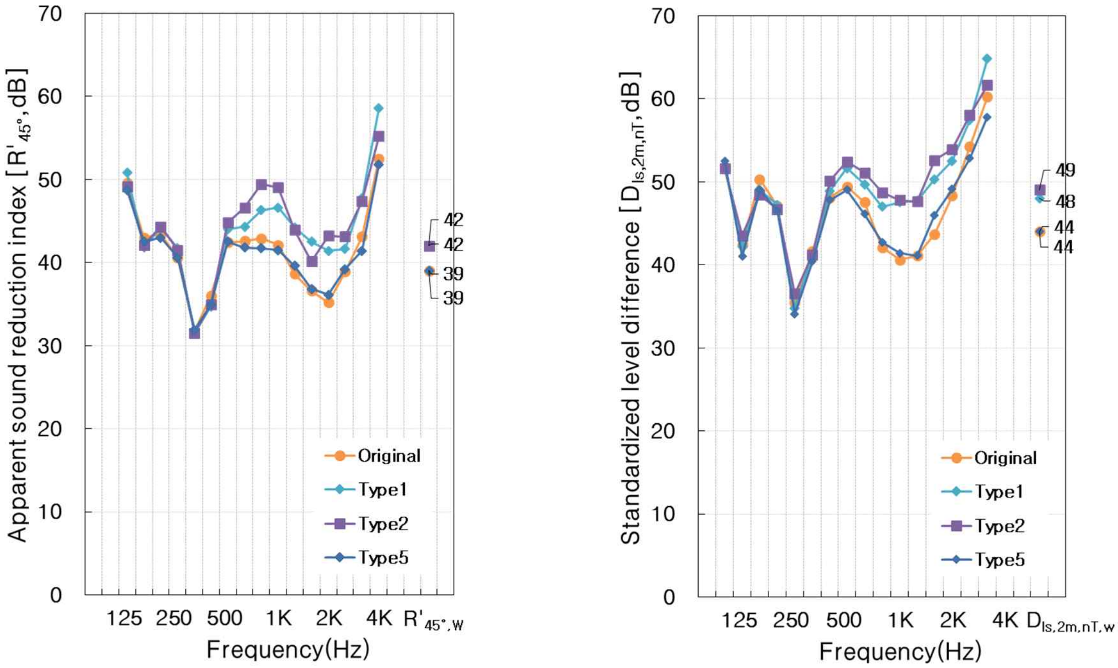
Figure 3: Changes in sound insulation performance according to application of sealant to the front door (Left)

Figure 4: Changes in sound insulation performance according to application of attachable door (Right)

The weighted apparent sound reduction index ($R'_{45°,w}$) of the front door in the laboratory apartment was 21 dB. $R'_{45°,w}$ was investigated according to a sealant type and the investigation result showed that Type 3 improved by 2 dB and Type 4 improved by 10 dB. $R'_{45°,w}$ was also investigated according to the developed types of attachable doors, and the results showed that when attachable door type Ⅰ was applied, it improved sound insulation performance by 13 dB and when attachable door type Ⅱ was applied, it improved by 15 dB. In particular, both types of the developed attachable door improved sound insulation performance at a range of frequency band between 1.25kHz and 2.5KHz significantly. The attachable door Ⅱ including damping pad revealed a better performance in the range of frequency band between 250 and 2000Hz than the attachable door type Ⅰ.

4.3 External windows

Figure 5 shows the airborne sound insulation performance according to the application of sealant and measurement method.



(a) Element method　　　(b) Global method

Figure 5: Changes in sound insulation performance according to application of sealant to external windows

As shown in Figure 5(a), a difference in the weighted standardized sound pressure level ($D_{ls,2m,nT,w}$) of existing windows was 44 dB according to measurement using the element method. When Type 1 was applied, it improved the sound insulation by 4 dB. When Type 2 was applied, it improved the sound insulation by 5 dB. As shown in Figure 5(b), a difference in the weighted apparent sound reduction index ($R'_{45°,w}$) of existing windows was 39 dB according to measurement using the global method. When Type 1 was applied, it improved the sound insulation by 3 dB. When Type 2 was applied, it improved the sound insulation by 3 dB. Thus, when type 1 and 2 sealants were applied, at least 3 dB or higher sound insulation performance was improved and no significant effect on sound insulation was exhibited due to the PVC wind block plate (Type 5).

5. Conclusions

This study aimed to block flanking noise that occurs in apartments in order to improve sound insulation performance and verified noise reduction effects by applying an improved method of sound insulation performance to parts differently. The study results showed that when wooden stud + glass wool + plaster board + putty was applied to both of the adjacent masonry walls, it improved sound insulation performance by 19 dB compared to that of general masonry wall (190 mm). The best sealant for front doors was a door sweep (Type 4), which improved sound insulation performance by 10 dB. Using the developed attachable door, sound insulation performance was also improved by 15 dB. The best performance for external windows was mohair brush seal (Type 2), which improved sound insulation performance by 5 dB. Noise transmission and delivery can be blocked by applying these various materials to fill the gap. It is necessary to improve applicability of various materials to aged apartments conveniently.

Acknowledgments

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