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Evaluation of Environmental Performance of Airtightness Improved Window

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Abstract

Windows are used not only for sun-shining and insulation but also for sound isolation and thermal insulation, and most of window frames installed in apartments are composed of either aluminum or P.V.C. In general, window consists of outer frame forming the opening and window frame attached glasses to, and there needs to be some space in the bottom and top side enough to put them together. Consequently this space at the top and bottom side becomes main factor affecting thermal and acoustic performance. Besides, both the degree of precision between frames and that of deterioration of mohair attached to window frame are related with environmental performance. This study aims to improve the environmental performance of window by constructing airtight attachments. The results could be effective in saving energy and natural resources, applying them to the windows deteriorated or the apartment which requires remodeling.

Keywords: Performance, Airtightness, Window

INTRODUCTION

Window is an important media along with wall among building members that partition the outside and inside of building space. Major role of window is to attract sunlight and sunshine and provide heat insulation, so improvement of building performance is focused mostly on these aspects. In general, energy loss occurring in buildings occurs through building wall, roof and window etc, and window has very high thermal conductivity compared with wall, so the amount of heat loss through window occupies 20 to 40% of all in case of houses. Article 21(Prevention of Heat Loss of Building) of Rules on Building Equipments etc also stipulates that building thermal conductivity shall be 0.36 W/m^2K or less for exterior wall of living room and 2.10 W/m^2K or less for window with reference to middle region.

Window is composed of external frame that comprises opening and internal frame(hereinafter "window frame") that includes glass, and a little bit of clearance space is required vertically when inserting window frame to outside frame. As a result, the space between the external frame and window frame created thus becomes major factor affecting heat insulation and sound insulation performances. At the same time, precision of the cross-section of window frame and aging of mohair used in window frame become the factors closely related with the environmental performance of window.

Studies on the environmental conditions to improve window performances are mostly focused on the evaluation of performances of thermal environment field(1,2) and sound environment field(3), and studies on designing high performance windows and doors have been conducted(4). Recently, studies on the use of energy through window and evaluation of CO_2 emission amount by it are being conducted through researches on the CO_2 reduction by global warming(5). In particular, the repair period and repair rate of windows & doors and glass, which are respectively 10 years and 2%, indicate that performances may deteriorate by aging.

In this study, the sound insulation performance, air-tightness performance and heat insulation performance of window were approached in consideration of sound and energy aspects among various environment performance elements related to window. Therefore, this study intended to examine the changes in environmental performance by improving the air-tightness performance of window, and solve the deterioration of air-tightness performance by aging of window frame and mohair. After air-tight structure is developed and installed to keep the space between window frame and outside frame air-tight, it was applied to window structure the most generally used in the nation, and the improved degree of sound insulation performance was evaluated. In domestic case, the heat insulation performance standard for apartment house window has been low in the past, and many windows are aged with time, so it is judged that this study results would be effective if the developed air-tight structure is applied to windows of low performance in existing apartment houses. In particular, in case window grows aged, it is deemed that performance deterioration may occur more significantly. In such situation, it is not easy in cost and resource aspect to repair window each time window performance drops, so reasonable and economical way of improvement is critical. According to the study of Nak-Hyeon Kim et al(6), CO_2 emission amount decreases through maintenance, and improvement of window performance among external housing heat insulation performance produces significant effect in reducing CO_2 emission amount. Therefore, it is anticipated that the air-tight structure developed in this study would be very effective method to save resources and reduce CO_2 by being applied at places where window aging is severe or in case remodeling is required.

MEASURING SOUND INSULATION PERFORMANCE OF WINDOW THROUGH LABORATORY EXPERIMENT

Structure of Experiment Subject

The sound insulation performances of window were measured on aluminum and PVC material the general materials of window in rectangular laboratory specified by ISO, and on glass which is used the most generally in apartment houses in practice. The glass used in window is general multi-layer glass composed as 16mm(5+6(air layer)+5), and it was treated to prevent occurrence of right turn abrasion with the finishing of specimen and wall processed with silicon. The specimen installed in the laboratory is 1.2m wide and 1.0 long, and an opening was created in the middle of the wall for measurement of the sound insulation performance of air transmitted sound. The wall near the opening which has sound insulation performance of Rw 70dB is judged to be sufficient in measuring the sound insulation performance of general window.

As for window composition, dual windows were considered as basic composition, and specifically dual window of both-sides PVC material and dual window of aluminum on the outdoor side and PVC material on the indoor side were taken in consideration of actually installed situations. Recently air-tight windows and doors called system windows and doors have been developed and are being used, but since they are not intended for performance improvement, environmental performance is relatively vulnerable, so generally used window structures were taken.

Table 1: Structure of experiment subject

lass	Type	Symbol	Outdoor side	Indoor side	Remark
1-1	New type	PP_N	PVC	PVC	Sound insulation
1-2		P_TP_T_N	PVC(Vertical, horizontal)	PVC(Vertical, horizontal)	Air-tightness
2-1	Old type	PP_O	PVC	PVC	Sound insulation
2-2		P_TP_T_O	PVC(Vertical, horizontal)	PVC(Vertical, horizontal)	
3-1	New type	AP_N	Aluminum	PVC	Sound insulation
3-2		A_TP_T_N	Aluminum(Vertical, horizontal)	PVC(Vertical, horizontal)	Air-tightness Heat insulation
4-1	Old type	AP_O	Aluminum	PVC	Sound insulation
4-2		A_TP_T_O	Aluminum(Vertical, horizontal)	PVC(Vertical, horizontal)	

※ Description of symbols
P : PVC window and door, PP : PVC dual window
A : Aluminum window and door, AP : Aluminum+ PVC dual window
N : New type structure
O : Old type structure
T : Installation of air-tight structure at vertical, horizontal part

The sound insulation performance of window is affected by various factors like window frame, glass composition, and installing precision etc, and the correlations of these factors and sound insulation performance are being studied to some degree(7). In this study, structure(old type) from which mohair of one side(sound source side with which loss is promoted due to exterior air effect) was removed from among the mohairs installed on both sides of window frame was considered to measure loss of mohair and deterioration of sound insulation performance by aging of window. Windows are bound to age with time, window performance deteriorates, and the reason is because mohair installed on window frame is lost while window air-tightness deteriorates by long use mostly. As for the measurement of the window composed in the experiment, the window was measured before and after installation of air-tight structure on dual window of PVC and aluminum + PVC. The measured window structure was intended to compare the performances of single window, dual window and air-tight structure, and particularly classified into new type and old type, the measurement was intended to examine the deterioration of sound insulation performance by loss of mohair and the effect by installation of air-tight structure. As for air-tightness performances, the performances before and after installation of air-tight structure for PVC dual window and aluminum+PVC dual window were measured and compared for comparison of the improved degree of air-tight performance over existing window. As for heat insulation performance, only PVC dual window was measured from the judgment that this study is an experiment on air-tight structure, and heat insulation performance does not differ significantly depending on window structure.

Measuring Window Performance

Regarding the environment performance of subject window, sound insulation performance, air-tightness performance and heat insulation performance were measured.

Measurement of the sound insulation performance of window was done in laboratory, and specifically the level of sound pressure in sound receiving room and the level in sound source were measured simultaneously after generating sound source(white noise) through the speaker installed inside the laboratory. From the measured values, Rw and STC value were calculated after the reverberating time in sound receiving room was calibrated.

As for the instruments used in the measurement, directional speaker(B&K Type 4224) and non-directional microphone(GRAS Type 40AR) were used, and as for analyzer, multi-channel measuring and analyzing instrument(Rion SA-01) was used. Figure 1 shows the diagram of experiment instrument that measures sound insulation performance in the reverberating room of ISO type.

In the experiment of air-tightness performance, specimen was installed to specimen connector frame(with opening side of 1.5m x 1.5m) according to KS F 2292:2003(8), and was tightened up to be solid enough to withstand testing pressure. After pressure of 250Pa was applied before measurement for 1 minute, stopped and checked, pressure differences were measured in sequential order for pressures of 10Pa, 30Pa, 50Pa and 100Pa.

Heat insulation performance test was conducted according to KS F 2278:2008(9), and the space between testing frame and specimen was finished with silicon as specimen of the same size as air-tight performance experiment after filling with urethane foam. For measurement of specimen surface temperature, T type thermocouples were attached at totally 9 locations in the center of each point by dividing the specimen to 9 parts equally. The coefficient of overall heat transfer was calculated by measuring the temperatures 3 times per hour in steady state, and as for final result, the average was used. The conditions and structure of experiment device are shown in Figure 1 and Table 2.

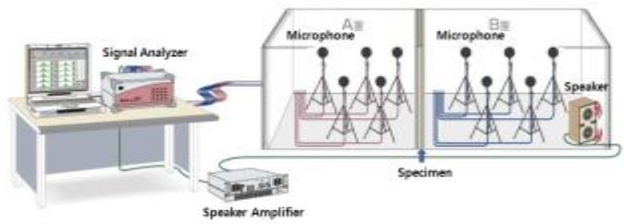

Figure 1: Diagram of experiment instrument composition

Table 2: Environmental conditions of experiment device

Chamber	Temperature (℃)	Humidity (% R.H.)
Constant temperature constant humidity chamber set condition	20.0	50
Heating box set condition	20.0	50
Low temperature chamber set condition	0	

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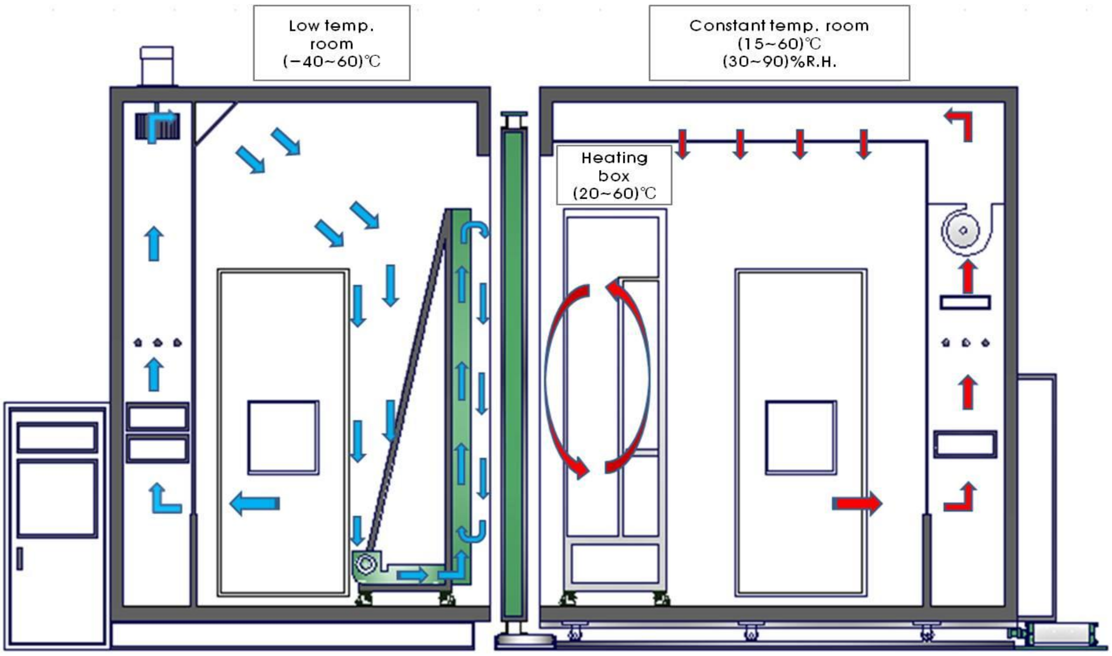

Figure 2: Heat insulation performance experiment device structure

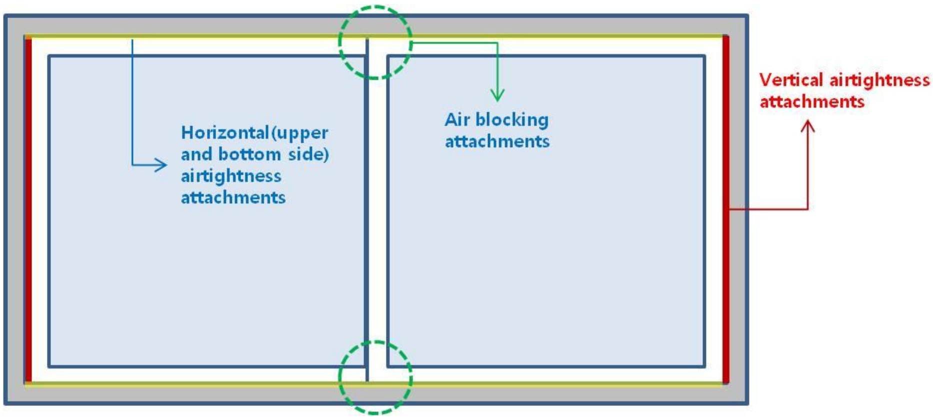

Figure 3: The concept of air-tight structure installation (Horizontal, vertical, gap sealing)

Installation of Structure with Improved Air-tightness Performance

The sound insulation performance of window is bound to deteriorate due to the gaps formed between outside frame and window frame, and this deterioration leads to decrease in air-tightness as well as thermal performance simultaneously and ultimately becomes the cause to increase indoor energy consumption. Therefore, in this study, a structure that minimizes the gap between window frames and ultimately raises air-tightness was installed, and the effect of the method of relatively simply installation on window frame on sound insulation performance and the change in performance by it were examined. Figure 3 and Figure 4 show the installation concept and details of air-tight structure respectively, and in the figures, air-tight structure indicates the gap sealing at the part where the horizontal member of vertical part, the vertical member of horizontal part and the left and right frames of window contact.

(a) Vertical(left, right) air-tight structure

(b) Horizontal(vertical) air-tight structure

Figure 4. Detailed issues of air-tight structure

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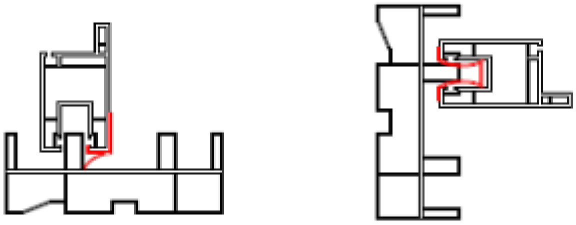
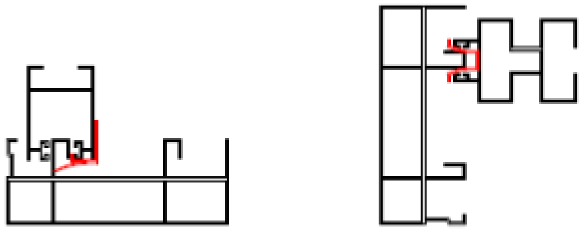
Figure 5 shows the cross-section of the air-tight structure installed on window frame, and Photo 1 the appearance of air-tight structure installed for laboratory experiment. The entity on the left in each figure indicates the installed cross-section of air-tight structure to be installed in vertical direction of window frame, and the right side the structure to be installed on the left and right sides of window frame. As for the method of window installation, the gaps in vertical direction which are more were judged affecting the performance more, so vertical direction was experimented first, and left and right direction was observed on the change of sound insulation performance after additional installation.

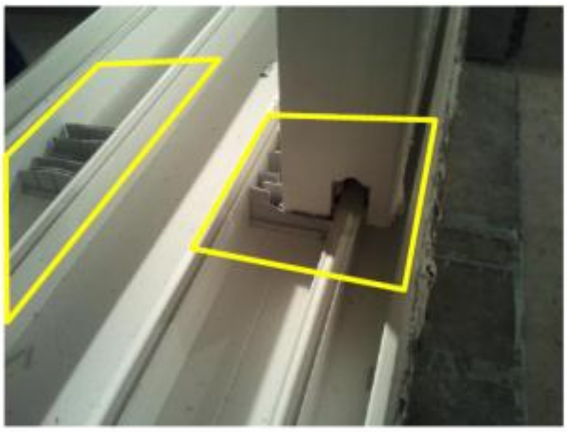


(a) PVC window



(b) Aluminum window

Figure 5: The cross-section of window frame where air-tight structure is installed



(a) Details of bottom part of gap sealing structure

(b) The horizontal air-tight structure installed at vertical part

(c) Vertical air-tight structure installed at horizontal part

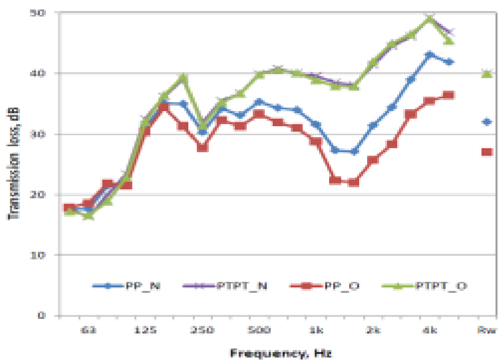
Photo 1. Air-tight structure applied during laboratory experiment

MEASUREMENT RESULTS

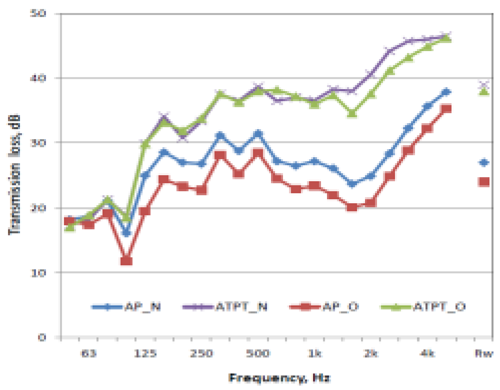
Sound Insulation Performances

The sound insulation performances of PVC dual window and aluminum+PVC dual window were measured, and then new type and old type were compared. For comparison of the measurement results of sound insulation performance, Rw values the evaluation method specified by ISO 717-1(10) and KS F 2862(11) were used. Figure 6(a) shows the comparison of the sound insulation characteristics of PVC dual window, and (b) the characteristics of aluminum+PVC dual window. The sound insulation performance of window was lower than the value of glass itself(7), and in particular, the sound insulation performance of glass itself increased with increase in frequency according to the law of mass, but in case of installation on the window, low value appeared in mid-high frequency bandwidth(12).

PVC dual window shows about 8 dB difference of sound insulation performance before and after installation of air-tight structure, and the sound insulation performance of old type structure that removed mohair was about 5 dB lower than that of the structure which did not remove mohair. Aluminum+ PVC dual window was found 5 dB or so lower than PVC dual window, but in case air-tight structures were installed on vertical, horizontal parts, the sound insulation performance was 1 to 2 dB lower than PVC dual window but remained at nearly the same level. This indicates that sound insulation performance was improved by the installation of air-tight structure.



(a) PVC dual window



(b) Aluminum+ PVC dual window

Figure 6: Comparison of the changes in sound insulation performances of dual window by installation of air-tight structure

Air-tightness Performance

Infiltration is one of the main reason of heat loss of building, and can be defined as unwanted ventilation because it is not easily controlled. Hear shows the airtightness change of the windows, which were already introduced from the previous research(12).

The figure in the research paper(Fig. 5) introduce the airtightness by the airtight structure attachment. The values indicate air-tightness performance improved significantly.

Heat Insulation Performance

Methods of improving window and door heat insulation includes increase of the number of glass, charging of gas in middle air layer, and decrease of radiation heat transfer through low emission coating etc. For quantification of heat insulation value, U value(coefficient of overall heat transfer) is used, and the U value of window reflects the heat insulation value of glass itself, the corner effect occurring in the insulated glass unit, window & door frame and chassis etc all.

The Ministry of Knowledge Economy has released "Regulation on Efficient Managing Instruments & Equipments Operation" based on the article 15 and article 16 of 2011 Act on Energy Usage Rationalization. The regulation on window set stipulates that maximum coefficient of overall heat transfer shall be limited to 3.4 W/m^2K, and efficient use of product through classification of consumption efficiency classification index based on the measurement of coefficient of overall heat transfer by KS F 2278 shall be promoted. Table 3 shows the consumption efficiency classification index. Owing to improvement of architectural techniques and development of members, the coefficient of overall heat transfer of window is decreasing. Though the value of coefficient of overall heat transfer of window is limited to 1.8 W/m^2K regarding the heat insulation performance of heat insulation member of building exterior wall, this value, which falls under the scope of grade 3 by the newly established consumption efficiency classification standard, indicates poor efficiency. Recently developed product is assigned grade 2 of consumption efficiency, but from July 2014, grade 2 or above is required.

Table 3: Criteria of assigning consumption efficiency grade

R	Air-tightness	Grade
R ≤1.0	1st grade	1
1.0<R ≤1.4	1st grade	2
1.4<R ≤2.1	2nd grade or above (1st grade or 2nd grade)	3
2.1<R ≤2.8	Not asked	4
2.8<R ≤3.4	Not asked	5

R(Consumption efficiency classification index) = coefficient of overall heat transfer (W/㎡·K)

In this study, which intended to look into the change in the heat insulation performance of window by installation of air-tight structure, the heat insulation values before and after installation were compared through installation of air-tight structure on PVC dual window. Therefore, this value is a value measured in the experiment based on the calories flowing through entire window like frame as well as glass. Figure 7 shows the values of coefficient of overall heat transfer of window measured before and after installation of air-tight structure. The measured value of coefficient of overall heat transfer falls within the scope of grade 2 of consumption efficiency classification standard. Also, this value satisfies the requirement of 2.10W/m^{2}K or less the coefficient of overall heat transfer of window and door specified in article 21 of Rules on Building Equipment Standard Etc, and thus it is shown that the PVC dual window in this study is one that can be used in buildings generally. As the coefficients of overall heat transfer are 1.33 W/m^{2}K and 1.27 W/m^{2}K respectively before and after installation of air-tight structure, the effect of installing air-tight structure is judged very low.

ANALYSIS AND DISCUSSION

The Effect of Air-tight Structure

Window plays very important role to building users in environmental aspects like sound insulation and ventilation as well as in functional aspects like view, sunlight and heat insulation. These performances are mutually related and yet maintain contradictory functions. Therefore, there are cases where improvement of one function may lead to elevation of the other function and deterioration of another. For instance, if air-tightness performance is improved, sound insulation and heat insulation performances may be lifted, but ventilation performance is likely to fall. If view is considered, sunlight grows plenty. Therefore, many techniques that improve window performance have been developed to improve the environment performance of window individually or to satisfy contradictory performance simultaneously. Individual techniques include enhancement of strength through reinforcement of window frame, blocking of sunlight through glass coating, improvement of air-tightness by cross-section designing, and improvement of ventilation performance through designing or development of ventilation device. Combined techniques include installation of blind and ventilation device for improvement of heat insulation performance and ventilation performance, acquisition of view and blocking of sunlight etc. As a result of analyzing window & door performance related techniques, air-tightness performance and gap blocking related techniques were the most, and specifically the technique of minimizing gap by attaching additive material to window frame occupied the highest ratio (21 cases out of 50). Therefore, in this study, the technique of acquiring heat insulation performance and sound insulation performance while improving air-tightness performance was adopted.

Windows composed of sliding component between window frame and outside frame, gaps are created mostly, so they deteriorate in sound insulation performance and air-tightness performance by it. If heat insulation structure is to reduce thermal conductivity by increasing thickness, air-tight structure has the advantage of being able to preserve indoor energy in thermal performance aspect as well as improve sound insulation performance as a result by blocking gap and reducing air flow. Air-tight structure was applied because it is economical due to easy installation by simple structure and generally available material, and as a result, air-tightness performance as well as sound insulation performance was significantly improved, and though heat insulation performance improves, but the degree of improvement is relatively small(Table 4).

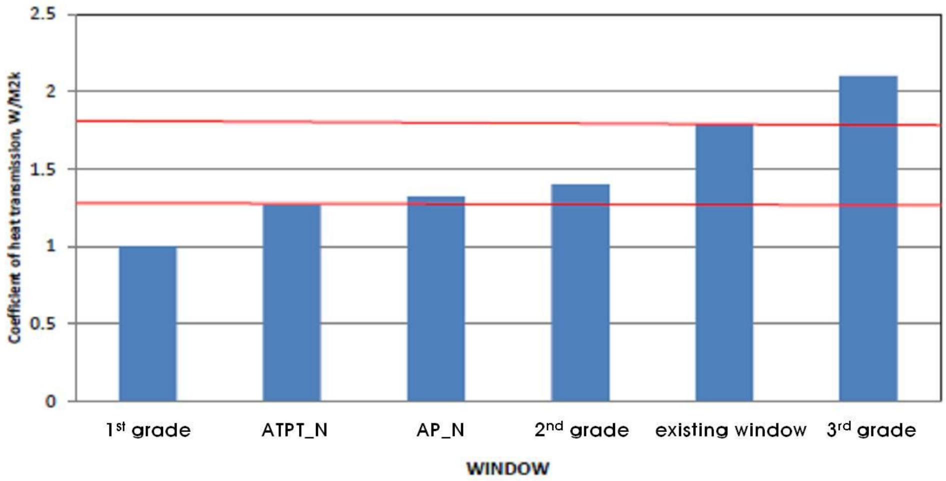


Figure 7: Comparison of changes in the heat insulation performances of dual window by installation of air-tight structure

Table 4: Comparison of environmental performances before and after installation of air-tight structure

Class	Type	Symbol	Sound insulation performance (Rw, dB)	Air-tightness performance(m^3/hm^2)	Heat insulation performance (W/m^2K)
1-1	New type	PP_N	32	Not measured	1.27
1-2		PTPT_N	40	11.5	1.33
2-1	Old type	PP_O	27	-	-
2-2		PTPT_O	40	-	-
3-1	New type	AP_N	27	Not measured	-
3-2		ATPT_N	39	13.28	-
4-1	Old type	AP_O	24	-	-
4-2		ATPT_O	38	-	-

As for dual windows where air-tight structure is installed respectively at vertical and horizontal part of window frame, sound insulation performance improved by 8 dB in case of PVC and 12 dB in case of aluminum +PVC dual window. In particular, old type dual window showed sound insulation difference of 3 to 5 dB compared with sound new type, but after air-tight structure is installed, the sound insulation performance showed a level nearly the same as new type structure where air-tight structure was installed. Such results indicate that if air-tight structure is applied to old window frame, the performance would become similar to new type, and thus in case the window grows aged, it can be remodeled in simple manner without undergoing complex construction.

Before and after installation of air-tight structure, air-tightness performance showed significant improvement, and though ventilation amount was as high as no measurement was possible, the performance improved very significantly after installation. In particular, the results indicate that the value is less than the standard value specified as grade 2 presently, air-tight structure may become a very effective method if it is applied to old window just as with the case of sound insulation performance.

Heat insulation performance showed very small improvement(5%) while sound insulation performance or air-tightness performance has improved significantly. Such results indicate that in case air-tight structure is installed on window frame, gap narrows down and thus air-tightness performance does not improve, but, heat insulation performance is not affected significantly. Heat insulation performance, which is measured by the difference of temperature among rooms after long hours heating and stabilizing of temperature, is affected by the material used in the window like glass, so heat insulation performance is judged not affected significantly by installation of air-tight structure.

Environmental Change by Application of Air-tight Structure

It was found that application of air-tight structure improves air-tightness performance and heat insulation performance along with sound insulation performance. Among these performances, air-tightness performance and heat insulation performance are closely related to building energy performance. In particular, it was found that new type and old type windows applied, the sound insulation performance of window that deteriorates with time, air-tightness performance and heat insulation performance can be improved significantly. This shows that use of air-tight structure in aged window of existing houses and apartment houses and windows of low performance produces the potential to improve energy performance. If the energy performance of window is secured, residents can stay warm indoors in winter. With the use of saved energy, the quality of indoor air can be improved, and by reducing use of materials, CO_2 emission amounts can be reduced ultimately.

A study on lifecycle CO_2 evaluation indicates that as a result of evaluating CO_2 emission amount by heat insulation condition, 3 to 10 kg-CO_2/m^2 emission amount was reduced in case of window and door, and in operation stage, average 1,102 kg-CO_2/m^2 was reduced(in case window area ratio is 35%). Therefore, by not replacing window and door and subsequently reducing use of materials, not only is CO_2 emission reduced, but also energy efficiency is improved by installation of air-tight structure, so it is shown that during lifetime, CO_2 emission amount can be saved very significantly. Greenhouse gas can be reduced by 90 to 300kg-CO_2/m^2 in case the area of window used in apartment house is 30m^2, and 92.5 ton-CO_2/m^2 in case floor area is 84m^2. Consequently, it is anticipated that installation of air-tight structure in the gap of window and door can lead to improvement of sound insulation, air-tightness and heat insulation performances, and ultimately produce very significant socio-economical effects.

CONCLUSIONS

Windows used in building not only are low in heat insulation performance compared with walls as they use glass, but also include gaps among window frames, so they become the factor that deteriorates air-tight performance. In particular, unlike those in general offices, windows in apartment house are sliding windows mostly instead of being air-tight window. Sliding windows include many gaps between window frames structurally, and they deteriorate in air-tightness performance with time due to elimination of mohair installed for air-tightness performance. This study intends to provide basic data on the repair and maintenance of window and door by measuring and analyzing sound insulation performance, air-tightness performance and heat insulation performance after applying the technique to keep gaps air-tight as a way to improve window performance.

It was found that through the experiment, air-tightness performance along with sound insulation performance improved significantly, and heat insulation performance also showed improvement, though the improvement amount is relatively small. As for sound insulation performance, improvement of about 8 dB performance was found after installation of air-tight structure, and the sound insulation performances of new type and old type windows indicated improvement of 5 dB. In particular, new type and old type windows showed sound insulation performances of similar level regardless of installation of air-tight structure, and thus indicated that installation of air-tight structure produced significant effect. Air-tightness performance value improved significantly after installation of air-tight structure, and indicated performance of grade 2 or less per KS F 2292. Such results indicate that installation of air-tight structure can not only improve energy performance of building but also save CO_2 emission amount. In particular, it is anticipated that economical installation of air-tight structure will be able to improve energy performance and reduce CO_2 emission amount significantly in operation stage.

ACKNOWLEDGMENTS

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