Appropriate technology to improve the condensation resistance of existing window

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Abstract. The dilapidated windows in old buildings lead to not only energy loss but also condensation, which can cause damages to finish materials and structures, which can adversely affect the residential environment of residents. In the research, in order to prevent the occurrence of condensation, the airtightness performance improvement technology of window(Windbreak) and the thermal insulation performance improvement technology of window(Attached glazing) were selected. Then, these two technologies were applied to real old apartment houses for performance verification. TDR (Temperature Differential Ratio) was calculated by measuring the surface temperature of the window before and after the application of the two technologies, and the quantitative evaluation was performed by comparing the measured values. As a result, the condensation prevention performance was enhanced by about 17.69% result for the installation of the attached glazing and the windbreak. Especially, it was more effective in the lower part of the glazing where condensations mainly occurs.

1. Introduction

Apartments are the representative residential building of the Republic of Korea and occupies about 75% of the entire houses in the country. About 58% of them are the dilapidated dwellings which are over 15 years old. Therefore demands for remodelling (and retrofit) to improving energy efficiency of existing buildings has increased. Also, various technologies have been developed recently. (S.H. Cho, 2018)

Windows are the main improvement subject which accounts for about 30% of the heat loss in buildings, and a thermal performance of windows is relatively lower than wall including a insulation. In addition, as time passes, air leakage occurs on windows result from load and corrosion or frame warping. Characteristics of such dilapidated windows cause not only energy loss but also condensation, which can lead to damages of finish materials and structures. It can adversely affect the residential environment of residents. There are various causes of high humidity and cold surface, which are two main factors of condensation occurrence, as shown in Table 1.

| Factor          | Description                                                                 |
|-----------------|-----------------------------------------------------------------------------|
| **High humidity** | High relative humidity due to hot and humid outside air, Low temperature in unheated space, Lack of ventilation, Low permeability resistance of skin material, Water vapor generation of residents |
| **Cold surface** | Infiltration of cold air, Defects by part of building, Lack of insulation performance, Lack of heating surface of solar radiation |
In this study, causes of condensation were blocked by using the condensation resistance technologies (Windbreak and Attached glazing), and these technologies were applied to actual apartment houses to verify the performance. The windbreak improves the airtightness performance of windows to prevent the penetration of cold outside air in the winter season and the attached glazing is a technology to improve the thermal performance of the glazing.

2. Technology for Preventing condensation
The most effective way to enhance airtightness and thermal performance of existing windows is to replace them with new windows that have good performance. However, there are difficulties such as high costs of window and rearrangement of household furnishings. In this study, it is aimed to improve the airtightness and thermal performance of the windows by applying low cost and high efficiency indoor retrofit technology and to confirm the effect of reducing condensation.

2.1. Windbreak
The windbreak is a technology designed to enhance the airtightness performance that prevents infiltration of outside air through a window. It can be applied to sliding windows mainly used in residential buildings in Korea. The principle is not complicated. It prevents leakage by installing windbreak on the junction of windows and window frames. In spite of the installation, windows can be opened and closed. The construction of windbreak can be done regardless of window size. Also, it can be installed directly by anyone without specific equipment, and it can be used semi-permanently because of its high durability. Appearances of the windbreak are shown in figure 1. The placement of windbreak is shown in figure 2.

2.2. Attached glazing
The attached glazing is a technology that ameliorates the thermal performance by attaching a polycarbonate board with an air layer of about 3mm on the glazings of windows. Thermal performance can be improved by maintaining the characteristics of windows such as solar radiation, view and ventilation. It can be installed regardless of the size of the window and can be installed easily by anyone without specific equipment. It can be used semi-permanently because it has high durability and can be designed by adjusting the Solar Heat Gain Coefficient (SHGC) and Shading Coefficient (SC) as needed. The appearance of windbreak is shown in figure 3. Figure 4 shows the location(section) of the attached glazing.

In the previous study, the performance improvement of window by applying windbreak and attached glazing was analyzed through mock-up experiment. The performance of the window itself and the performance after the application of the windbreak and attached glazing were compared. Thereby, the effects of the windbreak and the attached glazing could be confirmed quantitatively. The application of these two technologies improved the airtight performance by an average of 27.55% and the thermal...
performance by 15.70%. The lower performance of the existing windows, the more effective it is when the windbreak and attached glazing technologies were applied. (M.J. Bae, 2017).

Figure 3. The Appearance of attached glazing

Figure 4. The placement of attached glazing

3. Field Tests
In order to analyze the improvement of condensation prevention performance by applying the windbreak and the attached glazing, one of the apartment in Korea was selected and the field test was conducted. The experimental target is a typical Korean house, with veranda (unheated space) in the south and north, and the veranda is designed as an indoor space covered with windows to block the outside air. The photographs and drawings are shown in Figure 5.

Figure 5. The floor plan and Figure of subject of experiment

The condensation prevention performance is analyzed by calculating the temperature difference ratio (TDR) after measuring the indoor and outdoor air temperature and the surface temperature of the window. The surface temperature measurement locations of the window are shown in Figure 6. (The left figure is the south window and the right one is the north window)

Surface temperature measurements were implemented over 3 days of 2018.02.04 ~ 07 (before the application of the appropriate technology), and 3 days of 2018.02.15 ~ 18 (after the application the appropriate technology). The temperature was measured at night time (20: 00 ~ 05: 00), which is not influenced by solar radiation. During the experiment, the indoor temperature was maintained at 25 °C and the outdoor temperature was measured at -10 °C ~ 0 °C.
3.1. Result

As a result of analyzing the average surface temperature of the windows before and after applying the condensation resistance technologies, the surface temperature of all the windows was increased. (Table 2.)

Table 2. The average surface temperature of the windows before and after applying the condensation resistance technologies

|        | South -1 | North-2 | South -3 | South -4 | South -5 | North-1 | North-2 | North-3 | North-4 | Outdoor air |
|--------|----------|---------|----------|----------|----------|---------|---------|---------|---------|-------------|
| **Before** | 8.86     | 15.24   | 12.99    | 13.84    | 14.91    | 14.87   | 11.60   | 11.72   | -8.77   | -0.87       |
| **After**  | 12.95    | 19.20   | 15.68    | 19.30    | 17.76    | 19.16   | 16.12   | 15.10   | -1.58   | -1.58       |

Especially, the surface temperature of the 'South-4' is the most improved case at 13.84 °C before installation and 19.30 °C after installation. However, it is difficult to judge the improvement of the condensation prevention performance by simply the surface temperature since the outside air had not kept the same during the measurement period. Therefore, TDR was calculated and the results are shown in Figure 7. The average TDR of the windows decreased by 16.02% from 0.358 to 0.301 in the case of the south window, and decreased by 19.82% from 0.350 to 0.281 in the case of the north window after the application of the condensation resistance technologies. In particular, It was analysed that TDR reduction ratio of glazing bottom, the main condensation occurrence site, is high.

Figure 7. Average TDR before and after application of condensation prevention technology
4. Conclusion
In this research, in order to prevent condensation that occurs frequently in Korean apartment buildings, the improvement in condensation prevention performance by applying the thermal insulation performance improvement technology (attached glazing) and the airtight performance improvement technology (windbreak) of existing window was verified. As a result, the condensation preventing performance was improved by about 17.69%. The thermal performance of the glazing is improved due to the application of the attached glazing. In addition, the surface temperature of the window frames is improved by preventing the infiltration of the external cold air due to the application of the windbreak. In particular, it was analysed that TDR reduction ratio of glazing bottom, the main condensation occurrence site, is high. This result shows the characteristics of the attached glazing, which the lower performance of the existing window leads to the higher improvement in the thermal performance.

In this study, only one house was selected as a test subject. Therefore, there is a limit to the generalization of this result. In future research, additional experiments need to be conducted for houses with various type, areas, design, and window types, to find the most effective way of application of windbreak and attached glazing.

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