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Evaluation of the Basic Characteristics of Thermal Insulation Performance for Different Parts of Outer Walls that Considers Year-on-Year Change

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Abstract

Thermal insulation performance of existing building walls come to have lowered thermal characteristics compared to their early performance in accordance with years that have elapsed. In this regard, this study conducts a quantitative evaluation of the lowering of thermal insulation performance for different parts of the outer sidewalls of 25 apartment buildings, by calculating TDRo and SHF. The analysis shows that TDRo for the entire outer sidewalls decreased by an average of 13.4% every 5 elapsed years, and SHF increases discharged thermal energy by an average of about 7.8% every 5 elapsed years. Especially, the thermal insulation performance for the thermal bridges in between floors and walls is identified as a principal factor that lowers the thermal insulation performance of the outer sidewalls of a building.

Keywords: Infrared Camera, Apartment Housing, Thermal Insulation,Temperature Difference Ratio(TDR), Sensible Heat Flux

1 Introduction

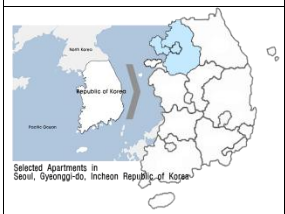
The thermal insulation of existing buildings basically registers low performance when compared to the designed legal standard for thermal insulation and the currently enforced standard for precision of the insulation work and its method. And as what is not intended in the original plan, it shows different thermal characteristics in proportion to the number of years elapsed after their completion due to year-on-year change and change in the physical properties of the walls [1][2][3][4]. Thus, the current study aims to classify apartments, which are Korea's major residential buildings, by portion of outer sidewall, and perform a quantitative evaluation of the influence that the year-on-year change in the physical properties of the walls exerts on the thermal insulation performance.

2 Methodology

2. 1 Targets of Measurement and Scope of Analysis

The study has selected for its analysis total 25 of apartment buildings, which take up minimum 58% of Korea's residential buildings (Statistics Korea, 2010), considering their location sharing one single legal requirement for thermal insulation, year of completion, and measurement environment.

Table 1.Objects of Measurement and Classification Criteria

Location	Classification of the year of Completion by group (5 years' interval)		
	Object for Measurement	Year of Completion	Buildings
	A group	Before 1989	5
	B group	1990 ~ 1994	5
	C group	1995 ~ 1999	5
	D group	2000 ~ 2004	5
	E group	2005 ~ 2010	5
	Total		25

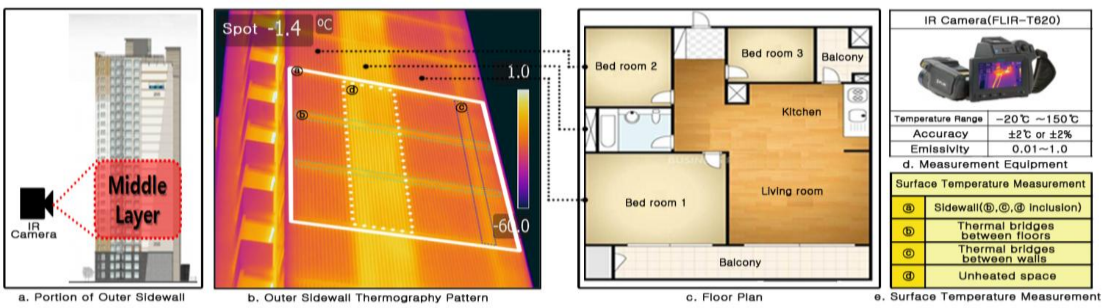


Fig 1. Scope of analysis of thermal insulation performance and overview of surface temperature measurement (Feb. 1, through Feb. 28, 2015)

The analysis focuses on the outer sidewalls for the eligible floors (5F to 10F) of apartment buildings, which are free from the influence of external environment in measurement and allows identification of the surface temperature for all the walls.The outer walls where surface temperature was to be measured included, as shown in Fig. 1 below, the entire outer sidewalls which directly faced indoor heated space and outer air (ⓐ), thermal bridges between floors (ⓑ), thermal bridges between walls (ⓒ), and unheated space (bathroom and utility room, ⓓ).

2. 2Measurement and Analysis Method

For measuring surface temperature, I have used infrared camera (FLIR-T620), which can capture temperature distribution at a single shot, and measured the temperature of outside air, indoor temperature, and the wind speed and humidity around the object, suing digital measuring device (TSI-8384). For analyzing thermal insulation performance, I have used Temperature Difference Ratio (hereafter referred to as TDR) and Sensible Heat Flux (hereafter referred to as SHF), which are to be described in detail as follows [5][6][7].

1) Outside Temperature Difference Ratio (TDRo)

TDR is divided into Outside Temperature Difference Ratio (TDRo), which evaluates the thermal insulation performance of outer walls, and Inside Temperature Difference Ratio (TDRi), which assesses the thermal insulation performance of inner walls, and is calculated using the difference (ΔT) between wall surface temperature, indoor temperature, and outside temperature. Thermal imaging was conducted according to KS F 2829 (2005), which is presented by Korean Standard Association based on ISO 6781[8][9]. In this study, I have evaluated the thermal insulation performance by using TDRo as calculated with Formula 1 below.

$$TDRo = \frac{To - Tos}{Ti - To} \qquad (1)$$

Where, Ti : Indoor Temperature(℃)
To : Outdoor Temperature(℃)
Tos : Exterior Surface Temperature(℃)

TDRo converges to 0, the better thermal insulation is, as the wall surface temperature gets closer to outside temperature, while it converges to -1, the poorer thermal insulation is.

2) Sensible Heat Flux(SHF)

Sensible heat flux (SHF) refers to the thermal energy that is absorbed or discharged without causing change to the condition during thermal change, and it is calculated using wind speed, outer wall surface temperature, and outside air temperature and in Formula 2 below.

$$H = \int_{allsurfacs} \alpha_{ci}(T_{s_i} - T_{air_i})dS \qquad (2)$$

Where, H : Sensible heat flux(kW)

α_c : Convective heat transfer coefficient (kW/m^2·℃)

T_S : Exterior Surface Temperature (℃)

T_{air}: Outdoor Temperature (℃)

S : Area(m^2)

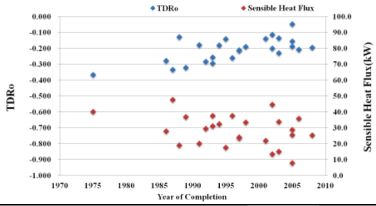
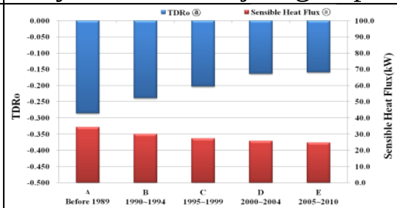
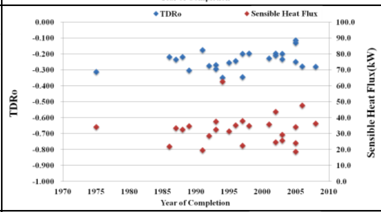
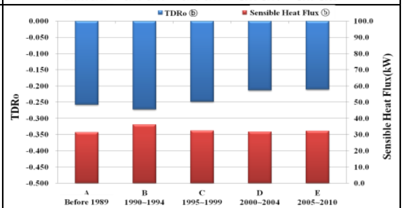
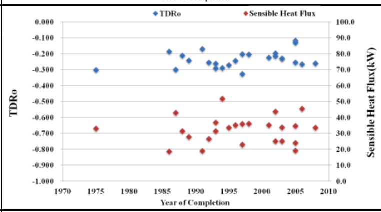
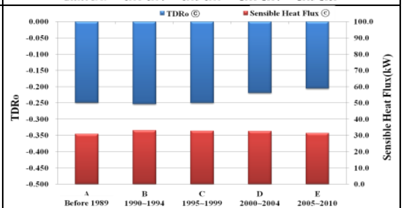
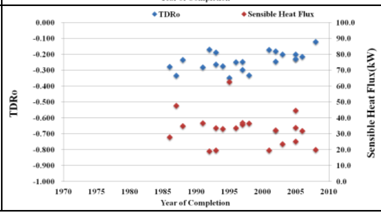
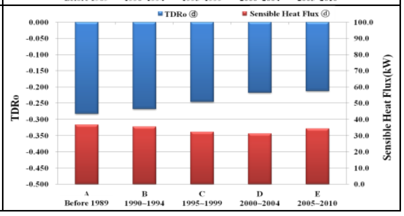
In SHF, the better thermal insulation is, the less thermal energy is discharged, and the poorer thermal insulation is, the more thermal energy is discharged.

3 Results and Discussion

3.1.Evaluation of Thermal Insulation Performance for Measured Parts

Table 2 below shows the results of the analysis related to TDRo and SHF per unit area.

Table2TDRo and SHF Analysis on Measured Parts

Measured part	By measured object	By measured object group
Entire outer sidewall ⓐ		
Thermal bridges between floors ⓑ		
Thermal bridges between walls ⓒ		
Unheated space ⓓ		

The thermal insulation performance analysis for different measured objects showed that TDRo and SHF tended to register lowering thermal insulation performance according to year of completion, that is, according to the number elapsed years. The results of evaluation of thermal insulation performance for different measured object groups (Table 1, A-E) are classified into measured parts as defined in Fig. 1, as follows.

1) Entire Outer Sidewall (ⓐ)

By measured object group, TDRo for entire outer sidewall decreased about 13.4% every 5 years starting from the year of completion, while coming lower 44.3%, 33.4%, 21.8%, and 3.0%, respectively for Group A, B, D, and D, as compared to Group E apartments (-0.159). SHF registered an increase in discharged thermal energy by an average of 7.7% every 5 elapsed years, growing 28.0%, 18.0%, 9.4%, and 4.0%, respectively for Group A, B, D, and D, when compared to Group E apartment ($32.5kW/m^2$). So, it is believed that the thermal insulation performance for entire outer sidewall (ⓐ) lowers due to change in the physical properties of walls in proportion to the number of elapsed years.

2) Thermal Bridges between Floors and Those between Walls(ⓑ, ⓒ)

At thermal bridges, TDRo came lower by an average of 11.8%, as compared to the analysis on the entire outer sidewall (ⓐ) for different measured object groups, while SHF increased about 28.0%. This is believed to be because the construction of most of the Korean apartments with internal thermal insulation necessitates the disconnection in insulating material at the junctures of walls and slabs, and it causes big difference between outside air and surface temperature, thus increasing thermal flow.

3) Unheated Space(ⓓ)

While the thermal insulation performance for unheated space in proportion to the number of elapsed years was similar to the results of the analysis of the entire outer sidewall (ⓐ), the decline in thermal insulation performance was slight. Every 5 elapsed year, TDRo decreased at an average of 6.8%, while SHF decreased at an average of 5.1% every 5 elapsed years from Group A to D apartments.

3.2Evaluation of Thermal Insulation Performance of Outer Wall Structure

Thermal insulation performance of walls must be designed and built above the standard thermal transmittance and continues to be upgraded. Therefore, thermal insulation performance at the time when a building was designed registers lower level of performance when compared to current legal requirement.

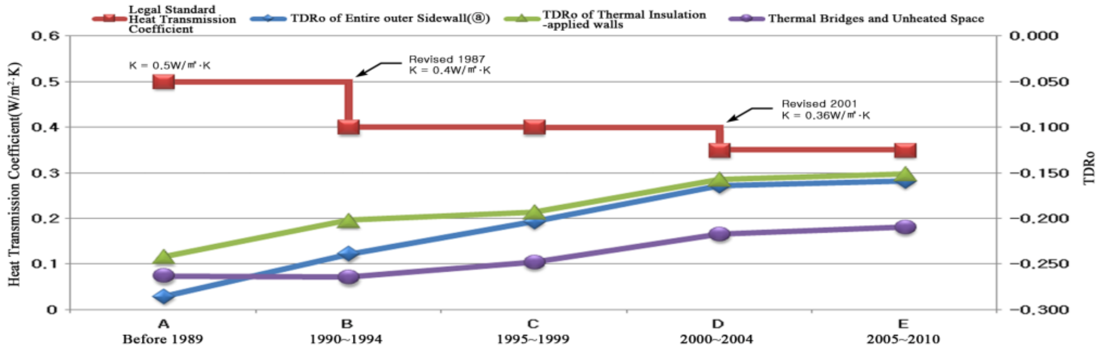


Fig 2.TDRoas figured out for different measured parts as compared to design requirement for thermal insulation

So, based on thermal transmittance and TDRo as the heat that is transmitted through the outer walls, I have analyzed the lowering of thermal insulation performance due to the year-on-year change in the physical properties of the walls as against the reinforced legal requirement for thermal insulation as shown in Fig. 2.The legally required thermal transmittance for the outer sidewalls that directly faced outside air was 0.36W/m^2·K for Group A apartments (2005-1010), thus improving thermal insulation performance by about 30% as compared to Group A (before 1989, 0.5W/m^2·K).Yet, in the average TDRo for the entire outer sidewall (ⓐ), Group A apartments came 44.3% lower as compared to Group E apartments. Thermal insulation performance lowered quite much as compared to the strengthening of legal design requirement for thermal insulation, due to the thermal insulation performance lowered by the difference in the legally specified thermal transmittance and changes in the physical properties of the walls such as year-on-year change, cracks inside and outside walls, and moisture content found in the thermal insulating materials that were applied on the thermal bridges with poor thermal insulation (ⓑ, ⓒ), unheated space (ⓓ), and the entire outer sidewall (ⓐ).

As for the average TDRo for thermal insulation-applied walls (ⓐ-ⓑ, ⓒ, ⓓ) excluding thermal bridges (ⓑ, ⓒ) and unheated space (ⓓ), Group A apartments came 37.6% lower than Group E. In view of the finding[10] in earlier studies that thermal conductivity diminished up to 35%, the thermal insulation performance lowered for the entire outer sidewall (ⓐ) is believed to be caused by not only the thermal insulation performance lowered by year-on-year change in the thermal insulating materials but also the change in the physical properties of the materials that constitute the walls.

As for the average TDRo for thermal bridges (ⓑ, ⓒ) and unheated space (ⓓ), Group A apartment came 17.5% and 24.7% lower than Group E, while the thermal insulation performance appeared lower through elapsed years than for the entire outer sidewall (ⓐ). However, since TDRo came lower by an average of 21.9% for thermal bridges (ⓑ, ⓒ) than for thermal insulation-applied walls, the thermal insulation performance for thermal bridges was perceived as a cause for thermal insulation performance lowered for the entire walls.

4Conclusion

The purpose of this study is to conduct quantitative measurement and analysis of the thermal insulation performance of existing buildings and use them as basic data for future studies. In this light, I have used TDR and SHF methods to quantitatively evaluate the year-on-year thermal insulation performance for different parts of the outer sidewalls of major apartment buildings.

For the entire outer sidewalls (ⓐ) of different measured object groups (Table 1), TDRo appeared to decrease by an average of 13.4% every 5 elapsed years. Furthermore, in the analysis of the lowered physical thermal insulation performance of structures as compared to the strengthened legal design requirement for thermal insulation, apart from the basic difference in performance deriving from the design requirement for thermal insulation, the year-on-year change in the thermal insulating materials and the change in the physical properties of walls due to the cracks inside and outside the walls and moisture content promoted the lowering of thermal insulation performance. Especially, the thermal insulation performance for thermal bridges (ⓑ, ⓒ) is believed to serve as a major cause for the thermal insulation performance lowered for the entire walls. And it is believed that a plan to reinforce thermal insulation should be drawn up for thermal bridges with the first priority.

Acknowledgements

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