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Condensation Prevention Performance Assessment Taking Into Account Thermal Insulation Performance Degradation Due to Aging for Apartment Housing

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ABSTRACT

Purpose: The current study analyzed trends in thermal insulation performance with aging, and condensation characteristics caused by the former. **Method:** Thermal insulation and condensation prevention performance of an architecture were assessed using Temperature Difference Ration Inside, or TDRi. Subjects of this quantitative analysis in thermal insulation performance change due to aging included recently constructed apartments and aged apartments older than 40 years. Time series comparison and analysis were conducted to observed changes in the thermal insulation performance and condensation characteristics. **Result:** Analysis showed that wall insulation performance degraded with aging regardless of fortified insulating material usage or insulating material type, which caused increased danger of condensation. In addition, when fortified insulating material was installed on the connection between the walls, insulation performance degradation was lower compared to cases in which fortified materials were not used. In all cases from 1 to 10, the rate of thermal insulation performance degradation increased after 20 years of aging.

KEYWORD

실내 온도차비율
공동주택
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Thermo-graphic camera

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1. Introduction

1.1. Research Background and Purpose

Of the total domestic residential buildings, apartment housing takes about more than 47% (Korea Statistics Office, 2013), and 27% is as old as 25 years after the completion of construction. Those aged apartment housing was designed and constructed with much lower standards of thermal insulation performance than the current insulation guideline. Furthermore, the degradation of thermal insulation performance by aging of apartment housing also aggravates residential environment such as with condensation by increasing quantity of heat the runs through door, window, and wall.

As people have recently paid more attention to residential environment due to frequent disputes, degraded living pleasantness and threat to residents' health due to condensation, the Ministry of Land, Infrastructure and Transport proposed condensation prevention design guideline for vulnerable areas (window, entrance door, wall junctions) for apartment housing with more than 500 households from May 2014.[1)]

However, it turned out that this guideline can not properly the risk of condensation of aging of apartment housing after completion since it measures thermal insulation performance based on the old criteria for condensation in window, entrance door, and wall junctions.

In this respect, the present study is aimed to supplement the guideline so it can measure condensation risk and performance based on the concept of life cycle management of a building rather than with old yardstick for initial thermal insulation performance. And this study examined the changes in thermal insulation performance and the characteristics of condensation by aging of apartment housing.

1.2. Method and Scope

To measure and evaluate thermal insulation performance and occurrence of condensation in existing buildings, this study employed Temperature Difference Ratio Inside (TDRi) recommended in 'Apartment Housing Condensation Prevention Design Guideline' of the Ministry of Land, Infrastructure and Transport.

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1) Apartment Housing Condensation Prevention Design Guideline, Ministry of Land, Infrastructure and Transport of Korea, 2013

For subjects to measure, this study selected apartment housing located in the same area applied by the same thermal insulation design guideline for internal/external wall (heat transfer coefficient) according to energy conservation design guideline[2]. The scope of measurement ranges from newly constructed apartment housing to aged apartment housing (more than 40 years old). And this study analyzed the changes of thermal insulation performance by aging of apartment housing quantitatively and the characteristics of condensation occurrence in time series.

For research method, a thermo-imaging camera was used to measure surface temperature of windows, entrance door, and wall junctions on spot and measuring instruments to measure weather conditions and indoor/outdoor temperature environment (temperature-humidity). The measured data were calculated into TDRi and thus thermal insulation performance and occurrence of condensation by aging of apartment housing were evaluated. Besides, other main research methods and procedures are as follows.

① To calculate TDRi as suggested in Apartment Housing Condensation Prevention Design Guideline, theoretical review was conducted on the characteristics and operation techniques of thermo-imaging camera, and requirements for measurement.

② The subjects to measure were divided in time series (by competition year) and thermo-imaging measurement, which was established through the theoretical review, was applied to the subjects for tsurface temperature. At the same time, digital measuring instruments were used on spot to measure the status of indoor/outdoor temperature environment by unit household.

③ With the data of surface temperature measured by the thermo-imaging camera, the first occurrence of condensation was evaluated at the environment conditions at the point of measurement. And the measured results were applied with indoor/outdoor temperature environment conditions suggested in Condensation Prevention Design Guideline to calculate TDRi again and thermal insulation performance analysis was conducted and occurrence of condensation was determined by the latest Condensation Prevention Design Guideline (TDRi).

2. Theoretical Review

2.1. Temperature Difference Ratio Inside (TDRi)

IR (infrared) thermo-imaging camera, which can capture the temperature distribution of windows and wall junctions at once, was used to measure surface temperature, and thermal insulation performance and occurrence of condensation were analyzed with calculated TDRi.

TDRi is an index to decide the thermal insulation performance and occurrence of condensation at the region of windows wall junctions and is also suggested in Apartment Housing Condensation Prevention Design Guideline. It is calculated at the conditions (Table 1) through Equation 1.

Table 1. Basic Measurement Conditions for Calculating TDRi

Measuring element	TDRi
Indoor temperature	Indoor temperature within 2m away from the internal wall surface (℃)
Outdoor temperature	Applying the outdoor temperature upon measurement
Interior surface temperature	-
Exterior surface temperature	Distribution of outer surface temperature of measured area
Wind velocity	· Ambient wind speed : Calculated TDRo upon 2 m/s · Maximum wind speed for TDRo measurement : Stopped the measurement when it was below 3m/s or above 3m/s · Measurement of the wind speed around the building is necessary (TDRo calibration is necessary in line with wind speed)
Measurement Time	Measurement can be done right before sunrise when the impact of insolation is minimized, but the shooting was done at least 8 hours after sunset.

$$TDRi = \frac{Ti - Tis}{Ti - To} \qquad (1)$$

Here,
Ti : indoor temperature (℃)
To : outdoor temperature (℃)
Tis : surface temperature of window and wall junctions (℃)

TDRi converges toward 0 because outdoor surface temperature is close to outdoor temperature when thermal insulation performance is high. Otherwise, it converges toward 1 (as thermal insulation is poor, outdoor surface temperature is close to indoor temperature.)

2.2. Infrared Imaging Technique (KS F 2829)

The surface temperature of a building was analyzed with the measured data of sections by an infrared imaging technique (ISO 6781 and KS F 2829).

Thermal imaging measurement can be done on the external skin of a part to be measured to gain the radiation factors of surface finish material or indoor/outdoor temperature depending on the usage of the instrument

2.3. Apartment Housing Condensation Prevention Design Guideline

It suggests the minimum performance standards of TDRi for apartment housing condensation prevention by area, as in Table 2.

2) Building Energy Conservation Design Standards', Ministry of Land, Infrastructure and Transport of Korea, 2013

Table 2. TDRi, Dew Condensation Prevention Performance

Measuring points			TDRo 1), 2)		
			South area	Central area	Cold weather
Door	exterior door /Shelter Fire doors	Leaf	0.30	0.33	0.38
		Frame	0.22	0.24	0.27
Wall Junction			0.23	0.25	0.28
Window	Glass Central region		0.16(0.16)	0.18(0.18)	0.20(0.24)
	Glass corner region		0.22(0.26)	0.24(0.29)	0.27(0.32)
	leaf / frame		0.25(0.30)	0.28(0.33)	0.32(0.38)

1) Entire parts should be met
2) ( ) is the criteria for aluminum windows.

According to the guideline, condensation performance(TDRi) for standard indoor/outdoor temperature environment is set by region: indoor temperature 25℃ and relative humidity 50% (dew point temperature 13.9℃); and outdoor temperature is −20℃ (severely cold region), −15℃ (central region), and −10℃ (southern region).

3. Evaluation of Thermal Insulation and Condensation in Apartment Housing

3.1. Evaluation Scope and Method

1) Subjects to Measure

As for the subjects to measure, the apartment housing located within the central regions (Seoul, Kyunggi Province and Inchone), where minimum TDRi performance is the same as suggested in Table 2, were selected. To analyze the thermal insulation performance degradation and characteristics of condensation by aging of apartment housing through life cycle, 10 apartment housings that were constructed from 1975 and 2014 were chosen. Table 3 shows the completion years of the subjects and thermal insulation designs (heat transfer coefficient) at the point of completion by section to measure.

Table 3. Overview of Measurement Target

Measurement Target	year of completion	Insulation Design Code(W/㎡·K)		
		Window	Door	Wall
Case 1	1975	-		1.0
Case 2	1986	3.5	-	0.6
Case 3	1991	3.5		0.6
Case 4	1992	2.9		0.5
Case 5	1995	2.9		0.5
Case 6	1995	2.9		0.5
Case 7	1999	2.9		0.5
Case 8	2001	3.8	3.8	0.47
Case 9	2011	2.1	2.1	0.36
Case 10	2014	1.5	1.5	0.27

2) Measurement Conditions

To measure the surface temperature of a building, a field survey was conducted meeting the requirements suggested in Table 1. Shooting date and weather conditions are as follows.

Measurement was conducted at night considering outdoor weather conditions, more than 10℃ gap between indoor and outdoor temperature, and no effect of day light. Table 4 summarizes the measuring conditions.

Table 4. Overview of Measurement Date

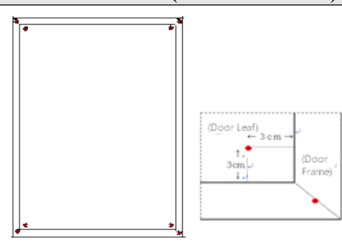
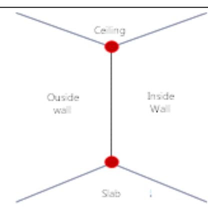
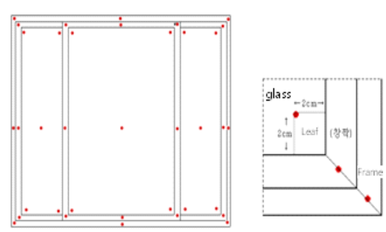
Date	2015.02.13 ~ 2015.02.28
Time	AM 05~07, PM 22~24
Weather Conditions	Day when the difference between indoor and outdoor temperature was at least 10℃
	Day when the wind speed was below 3m/s
	Day when the amount of clouds was below 7 (clear)
	Excluding rainy or snowy days and the next day

Surface temperature by section was taken with a IR thermo-imaging camera (FLIR T-620). To reduce measured temperature and radiation factor error, additional factors were calibrated with touch-type thermometer (TESTO 905-T2) before measuring. In addition, Indoor/outdoor temperature and humidity on spot were measured with multi-functional digital measuring instrument (TSI-8384).

3) Sections to Measure

As seen in Table 5, surface temperature was measured on the sections or parts as suggested in Apartment Housing Condensation Prevention Design Guideline. Figure 1 shows the areas where condensation occurs on the plane .

Table 5. Measurement Location of TDRi

Measuring points			Location of TDRi(Standard of Korea)
Door	Leaf	Corner	
		Central	
	Frame	Corner	
Wall	Junction		
Window	Glass	Corner	
		Central	
	Leaf	Corner	
		Central	
	Frame	Corner	
		Central	

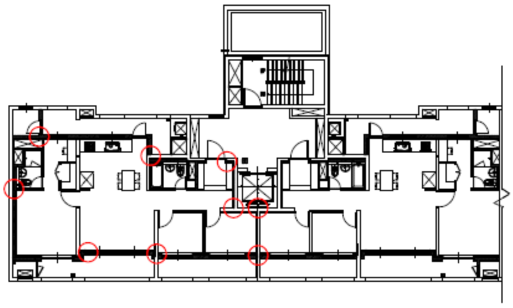


Fig 1. Possible Condensation Area

3.2. Surface Temperature Analysis by Section to Measure

Table 6 shows the averaged surface temperature of indoor/outdoor temperature environment measured on the field survey and measured for 4 hours (Table 4) by section (Table 5).

Table 6. Environments Condition, and Average of Surface Temperature

Case N	Temp		Indoor Humidity (%)	Dew Point (℃)	Surface Temperature(℃)					
					Door		Wall Junction	Window		
	In	Out			Leaf	Frame		Glass Central	Glass Corner	Leaf / Frame
1	22.8	4.7	38.9	8.1	17.8	18.4	17.2	21.6	20.4	20.7
2	18.7	5.0	58.2	10.4	12.9	12.0	10.6	17.2	16.1	16.0
3	22.3	0.3	37.7	7.0	11.9	11.3	16.3	18.9	17.8	18.2
4	18.6	1.0	35.6	3.1	5.4	6.9	9.5	16.4	14.1	13.1
5	18.3	0.1	41.4	5.0	15.4	16.1	9.8	17.8	15.7	14.2
6	21.1	-0.4	37.6	6.1	17.7	17.8	14.1	18.7	17.7	17.4
7	22.3	0.3	57.4	13.5	17.0	17.1	17.4	21.7	20.2	20.9
8	23.0	1.1	32.8	5.8	16.9	17.5	15.7	22.5	20.4	19.9
9	20.1	-4.0	49.5	9.3	15.3	14.8	15.4	19.1	17.1	18.2
10	18.5	0.1	53.4	8.9	14.3	13.4	14.0	16.8	16.0	16.9

The results show that no occurrence condition (surface temperature〉dew point temperature) of condensation was found under indoor/outdoor temperature environment at the point of measurement. And when actual bare-eye inspection on unit households, no condensation was observed on the sections to measure.

The results in Table 6 reflect not only the difference in thermal insulation performance by section to measure, but also indoor/outdoor temperature environment conditions (temperature-humidity), which is different by section to measure. Therefore, it is not right to compare and analyze change in thermal insulation performance and the characteristics of condensation occurrence by aging of apartment housing with the measure data in that way. For the reason, this study recalculated the measured surface temperature (Table 6) by Equation 2 at the same condition of indoor/outdoor temperature environment (Apartment Housing Condensation Prevention Design Guideline, the Ministry of Land, Infrastructure and Transport). The results are seen in Table 7.

$$\theta_r'' < \theta_s = \theta_r - \frac{K}{\alpha_i}(\theta_r - \theta_o) \qquad (2)$$

Here,

K : Heat Transfer Coefficient (W/㎡·K)
α_i : Indoor Surface Heat Transfer (W/㎡·K)
θ_r : Indoor Air Temperature (℃)
θ_s : Surface Temperature(℃)
θ_o : Outdoor Temperature(℃)
θ_r'' : Dew Point Temperature (℃)

Table 7. The Surface Temperature Re-analysis of The Results by Region in Accordance with The Environmental Conditions Correction

Case N	Standard Environmental Conditions	Surface Temperature(℃)					
		Door		Wall Junction	Window		
		Leaf	Frame		Glass Central	Glass Corner	Leaf / Frame
1	Inside Temp : 25℃ Outside Temp : -15℃ Indoor Humidity : 50% Dew point Temp : 13.9℃	14.0	15.3	12.5	22.4	20.1	20.3
2		8.1	5.3	1.3	20.6	17.6	17.0
3		6.3	5.3	14.4	19.3	17.4	17.7
4		-5.0	-1.6	4.4	20.0	15.2	12.4
5		18.7	20.1	6.4	23.9	19.5	15.9
6		18.6	18.8	12.0	20.5	18.8	18.1
7		15.4	15.6	16.1	23.9	21.5	22.4
8		13.8	15.0	11.7	24.1	20.6	19.3
9		17.0	16.2	17.2	23.4	20.2	21.8
10		15.9	13.8	15.2	21.3	19.8	21.5

According to the recalculated surface temperature under the same indoor/outdoor temperature environment conditions, the shades in Table 7 have conditions for the occurrence of condensation. And of the sections to measure, wall junctions had higher frequence of condensation occurrence then in entrance door and windows.

3.3. TDRi Analysis by Section to Measure

Table 8 shows the results of TDRi calculations (Equation 1) by section on which the recalculated surface temperature in Table 7 was reflected.

Table 8. TDRi, Measurement Target Calculation Results

Target	Average of TDRi					
	Door		Wall Junction	Window		
	Leaf	Frame		Glass Central	Glass Corner	Leaf / Frame
Case 1	0.28	0.24	0.31	0.07	0.12	0.12
Case 2	0.42	0.49	0.59	0.11	0.19	0.20
Case 3	0.47	0.49	0.29	0.14	0.19	0.18
Case 4	0.75	0.67	0.52	0.13	0.25	0.31
Case 5	0.16	0.12	0.47	0.03	0.14	0.23
Case 6	0.16	0.16	0.32	0.11	0.15	0.17
Case 7	0.24	0.24	0.22	0.03	0.09	0.07
Case 8	0.28	0.25	0.33	0.02	0.11	0.14
Case 9	0.20	0.22	0.19	0.04	0.12	0.08
Case 10	0.23	0.28	0.25	0.09	0.13	0.09

According to the results of occurrence of condensation analysis based on TDRi, the shades in Table 8 have conditions for the occurrence of condensation more than the minimum performance standard (Table 2) suggested in Condensation Prevention Design Guideline.

For entrance door, TDRi higher than condensation prevention minimum performance standard (door 0.33, doorframe 0.24) were found on Case 2, 3, 4 both door and doorframe, only in doorframe of CASE 8 and 10. Eventually, it turned out that 5 subjects have the condition for condensation in entrance door.

For window, TDRi at the center of window turned out lower than condensation prevention minimum performance standard (0.18) for all the subjects. TDRi at window corner, window pane, and window frame was found higher than minimum performance standard (window corner 0.24, window pane and window frame 0.28) only in Case 5. Therefore, only one subject the condition for condensation in window.

For wall junctions, TDRi was found higher than condensation prevention minimum performance standard(0.25) in 7 out of total 10 subjects. Of them, most (more than 20 years old) were built before 1995.

According to the results of TDRi calculations by section, wall junctions have the frequency of condensation occurrence in proportion to building age while the frequency of condensation occurrence is not related to use year of door and window. This phenomenon can be possibly explained by the fact that the field survey found users replaced or repaired entrance door and window due to infiltration by spacing between pane and frame, twist by long use and/or malfunction other than thermal insulation performance degradation. Unlike wall (junctions), however, degradation in thermal insulation performance of aged apartment housing was not directly observed. On the other hand, wall junctions has not been replaced or repaired, but used the same as at the point of construction completion. Therefore, they show thermal insulation performance degradation and the frequency of condensation occurrence, which are proportionate to building year .

Therefore, Relating thermal insulation performance degradation by aging of apartment housing to the characteristics of condensation is fairly agreeable with the purpose of this study. Thus, this study carried out detailed analysis on the changes in thermal insulation performance by aging wall junctions, rather than entrance door.

3.4. Thermal Insulation Performance Analysis of Wall Junctions by aging of apartment Housing

Figure 2 shows legal thermal insulation design guideline (heat transfer coefficient) of walls (contacting directly open space) by the year of completion and the results of TDRi calculation (Table 8). This study chose non-expansion unit households to evaluate the thermal insulation performance of wall junctions and condensation performance. The results are shown in Figure 2.

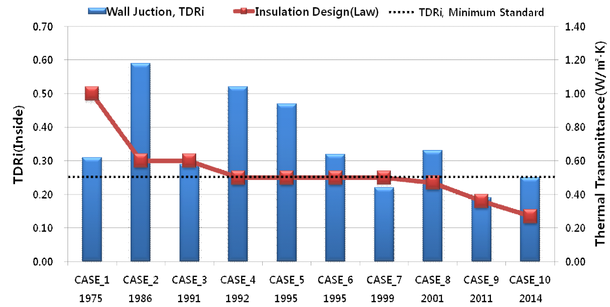


Fig 2. The Average TDRi Results of The Measurement Target-wall junctions

7 subjects out of the total 10 showed higher TDRi for condensation performance than minimum performance standard (0.25), which evidences they (7 subjects) are subject to the conditions for the risk of having condensation.

As seen in Figure 2, the legal thermal insulation design guideline for walls contacting open space has been reinforced. In case of 2010 as the year of completion, wall heat transfer coefficient (based on design) of Case 10 is 0.27W/㎡·K, which is 2.7 times stricter than Case 1 (as of 1975, 1.0W/㎡·K).

According to the results of TDRi in Figure 2, however, TDRi does not proportionately and uniformly lower to the reinforced thermal insulation design guideline. It has an irregular trend.

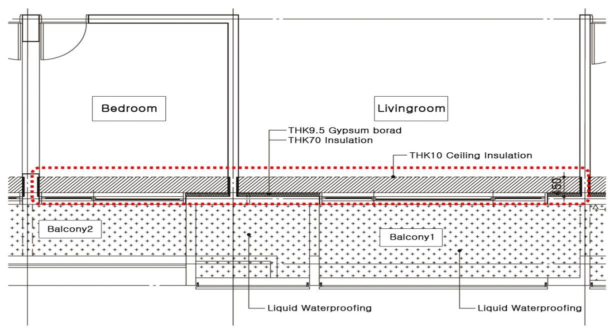


Fig 3. Wall Junction Reinforced Insulation Construction Case

When each of drawings and specifications are compared with TDRi results by subject to measure, as seen in Figure 3, the reason is found in the impact of the applicability of reinforced thermal insulation material and the types of applied thermal insulation material. To evaluate thermal insulation performance degradation by aging of apartment housing and thus the characteristics of condensation performance, which this study aims for, this study separated the results of Figure 2 between the results from the subjects constructed with reinforced thermal insulation material and those without. And another analysis was carried out the sorted data.

Figure 4 shows TDRi of the subjects that did not apply reinforced thermal insulation material to wall junctions for the purpose of condensation prevention and the heat transfer coefficients of outer walls calculated from the legal thermal insulation design guideline (heat transfer coefficient) for out wall and drawing analysis.

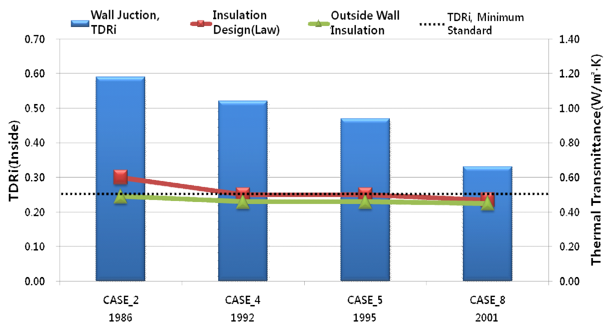


Fig 4. Wall Junction TDRi Results(Non-Reinforced Insulation Construction)

As seen in the results, all of Case 2, 4, 5, and 8, which are the subjects that did not apply reinforced thermal insulation material to wall junctions for the purpose of condensation prevention, show satisfactory level of outer wall heat transfer coefficients with legal thermal insulation design guideline. In Case 8 whose the year of completion is 2001, wall heat transfer coefficient (based on design) was 0.45W/㎡·K and turned out more reinforced by 8.2%, 2.2%, and 2.2% than the heat transfer coefficients of Case 2, 4, and 5, respectively.

According to TDRi results, TDRi of Case 2, 4, and 5 were 0.59, 0.52, and 0.47, respectively and when compared with Case 8 (0.33), they were higher by 44.1%, 36.5%, and 29.8%, respectively. In addition, all of them met the minimum performance standard (0.25), which means they have condition for the occurrence of condensation.

Like this, TDRi of the subjects that did not apply reinforced thermal insulation material to wall junctions shows change more than simple difference of wall thermal insulation value (heat transfer coefficient) and the difference between TDRi applied with the heat transfer coefficient of wall junctions in design and the measured TDRi turned out to be 0.54, 0.47, 0.42, and 0.28 in Case 2, 4, 5, and 8, respectively. It clearly demonstrated that the thermal insulation performance of outer wall degrades by aging of apartment housing.

Figure 4 shows TDRi of the subjects that applied reinforced thermal insulation material to wall junctions for the purpose of condensation prevention and the heat transfer coefficients of outer walls calculated from the legal thermal insulation design guideline (heat transfer coefficient) for out wall and drawing analysis.

This study examined the design method of reinforced thermal insulation material through the drawings and found that most of the subjects were installed with reinforced thermal insulation material in wall junctions to prevent condensation from mid and late 1990s. However, there is no standard for reinforced thermal insulation for wall junctions before the current Condensation Prevention Design Guideline was enacted. Therefore, the thermal insulation material varies in type, thickness, and length by subject building and thus construction methods are also different.

For example, Case 1, 3, 7, and 9 used THK 10 expanded polystyrene (EPS) while Case 6 and 10 used THK 5 extruded polystyrene (XPSS). As a result, they showed difference in thermal insulation performance as seen in Figure 5, which eventually led to the difference in condensation prevention performance (TDRi).

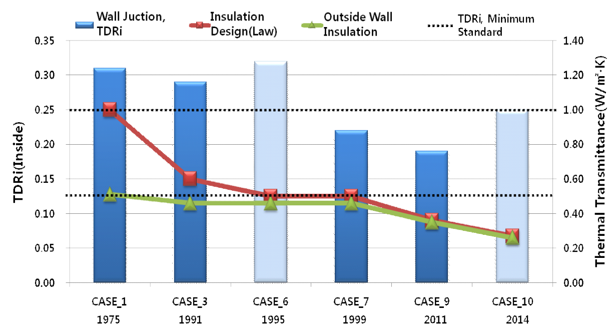


Fig 5. Wall Junction TDRi Results(Reinforced Insulation Construction)

Of the subjects that used expanded polystyrene (EPS), Case 9 whose the year of completion was 2011 has wall heat transfer coefficient (based on design) of 0.35W/㎡·K, which is more reinforced by 45.7%, 31.4%, and 31.4% than the heat transfer coefficients of Case 1, 3, and 7, respectively. According to TDRi results, TDRi of Case 1, 3, and 7 was higher by38.7%, 34.5%, 13.6% than Case 9 (0.19), respectively. Both Case 1 and 3 met the minimum performance standard (0.25), which means they have conditions for the occurrence of condensation.

Case 6 and 10 which used extruded polystyrene (XPSS) have wall heat transfer coefficient (based on design) of 0.46W/㎡·K, and 0.26W/㎡·K, respectively, and the thermal insulation design guideline was more reinforced by 46.0%

(Case 10) compared with Case 6. According to TDRi results, TDRi of Case 6 is 0.32, meeting the minimum performance standard (0.25), which means they have conditions for the occurrence of condensation. It is 21.9% higher than TDRi of Case 10 (0.25).

Next, Figure 5 shows the difference between TDRi(①) that is calculated based on heat transfer coefficients designed at the point of the completion and TDRi(②) calculated with surface temperature measured at wall junctions, which is eventually thermal insulation performance degradation by building year.

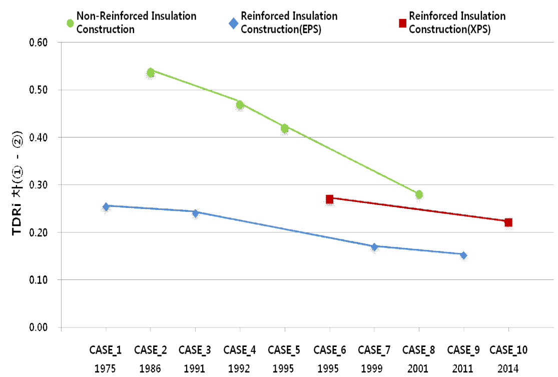


Fig 6. Measurement Target-Wall Junction TDRi Rate of Decrease Results

As seen in the difference in TDRi(①-②) of Figure 6, all the subjects show degrading thermal insulation performance regardless of the application of reinforced thermal insulation material in proportion to aging of apartment housing and consequently high risk of condensation occurrence. In addition, the subjects without reinforced thermal insulation material at wall junctions have slower rate of thermal insulation performance degradation aging of apartment housing than those with lower reinforced thermal insulation material at wall junctions. Finally, all the subjects older than 20 years of building life showed high risk of thermal insulation performance degradation.

4. Conclusion

The present study analyzed thermal insulation performance by aging of apartment housing and the characteristics of condensation occurrence, aiming to supplement a design guideline to control the risk of condensation through life cycle of a building. The main findings are as follows.

First, wall junctions, unlike entrance doors and windows that users replace or repair, has been used at the same structural state as the beginning of completion of a building and thus show apparent degradation of thermal insulation performance proportionate to aging of apartment housing. as a result, the frequency of condensation occurrence at wall junctions is higher than other sections to measure.

Second, regardless of using reinforced thermal insulation material and types of thermal insulation material, walls continue thermal insulation performance degradation by aging of apartment housing. as a result, it turned out that walls have high risk of condensation occurrence. TDRi in a building without reinforced thermal insulation material showed high degradation rate in all the subjects to measure due to aging of apartment housing more than wall thermal insulation design standard. The subjects built with reinforced thermal insulation material also showed continuous degradation of thermal insulation performance, though slightly different by he types of thermal insulation material, that is, high risk of condensation occurrence.

Third, when compared with buildings without reinforced thermal insulation material at wall junctions, those with reinforced thermal insulation material at wall junctions show lower rate of thermal insulation performance degradation by aging of apartment housing. It was proved that thermal insulation performance degraded by aging of apartment housing to considerable extent in all the subjects (Case 1 to 10) from the 20th year of completion.

Judging from the results above, as a building gets older, wall thermal insulation performance degrades by aging of apartment housing in all the subjects and consequently the risk of condensation occurrence rises. Therefore, Condensation Prevention Design Guideline should be amended in consideration of changes in thermal insulation performance by aging of apartment housing and a standardized thermal insulation installation plan needs developing in an effort to secure residents' healthy and dwelling pleasantness through life cycle of a building, as well as to avoid dispute due to condensation at the early period of completion.

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Reference

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