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The method of in-situ ASTR method diagnosing wall U-value in existing deteriorated houses

- Analysis of influence of internal surface total heat transfer rate -

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ABSTRACT

Purpose : Currently, 25% of the domestic energy consumption structure is used as building energy, and more than 18% of this energy is consumed in the residential. Accordingly, various efforts and policies that can save energy of the building is being performed. The various researchers are conducting research to diagnose the thermal performance of existing buildings. This study is to apply in the field of precision thermal insulation performance diagnostic method for thermal performance analysis of existing detached house in Seoul, Gangreung, Gyeongju, Pohang. And this paper is analyzed quantitatively measure the existing detached house energy performance. **Method:** Research methodology analyzed the thermal performance over the Heat Flow Meter method by applying the measurement process and method by applying the criteria of ISO 9869-1 & ASTR method. In this study, the surface heat transfer coefficient was calibrated by applying indoor surface heat transfer resistance with reference to ISO 6946 standard. The measurement error rate between the HFM diagnosis method and the ASTR diagnosis method was reduced and the measurement reliability was obtained through measurement method error verification. **Result :** As a result of the study, the thermal performance vulnerable parts of the building were quantitatively analyzed, and presented for methods which can be improved capable of efficient energy use buildings.

KEYWORD

기존 노후 주택
에너지효율개선사업
벽체 열관류율 진단
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Existing deteriorated houses
Houses energy efficiency treatment Program
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1. Introduction

Currently, 25% of the domestic energy consumption is used as building energy and more than 18% is consumed in the residential sector.[1)] Although energy saving and greenhouse gas reduction efforts are required in the housing sector, which occupies a high proportion in the building sector, there is a limit to energy saving and greenhouse gas reduction policies through the policy of strengthening housing energy performance of newly built houses, and there is a need for measures to reduce building energy and greenhouse gas emissions through energy efficiency improvement measures for existing deteriorated houses where energy loss occur due to degraded building performance rather than newly built houses. Currently, existing deteriorated houses constitute the majority of households whose energy efficiency has deteriorated by about 50% over 20 years. Currently, countries are also implementing policies to improve energy efficiency and efforts to reduce building energy in existing deteriorated houses. However, in the case of the improvement project through the current building energy diagnosis, there is not much reliable field diagnostic method to analyze the data related to building insulation performance of existing deteriorated houses. Therefore, it is necessary to quantitatively analyze the building energy performance of the existing deteriorated houses and to study the precise diagnosis method to measure wall U-value in the field. In this study, to diagnose wall U-value of actual existing deteriorated houses, it measured wall U-value ratio of building and acquired and analyzed long-term data by applying the high precision wall insulation performance diagnosis method performed in the previous study 2) And, it analyzed long-term wall insulation performance of the building envelope before and after building construction for existing deteriorated houses over 25 years. In this study, it analyzed wall insulation performance of existing deteriorated houses by using HFM (Heat Flow Meter) wall insulation performance precise diagnosis method proposed in the international standard ISO 9869-13, which is wall insulation performance diagnose method to diagnose wall insulation performance, and ASTR (Air-Surface Temperature Ratio) wall insulation performance simple diagnosis method which uses indoor/outdoor temperature difference.

As a result of comparing the measurement results of precision diagnosis method and simple diagnosis method in previous studies,

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error rates of 20% or more generated. In the simple diagnosis method performed in the previous studies, we conducted the study by applying indoor wall surface thermal transmittance rate 9W/(m2·K) value, indoor surface thermal transmittance resistance reciprocal value proposed in the Building Energy Saving Design Standard(2016)

In this study, we calibrated the indoor surface thermal transmittance rate by applying the reciprocal value of indoor surface thermal transmittance resistance by referring to the standard ISO 69464)(Building components and building elements − Thermal resistance and thermal transmittance − Calculation method), and reanalyzed measurement error rate through the comparison with the existing study method.

In this study, the following studies were conducted to analyze the insulation performance of existing deteriorated houses according to the wall measurement method. First, Rossano Albatici. Et al5) verified the reliability of diagnostic method and the experimental method through 3-year experiment of building wall U-value, and analyzed the error rate of the diagnostic method through experiments. To analyze building energy performance for existing buildings and new buildings, we analyzed the variance of U-values through sensitivity analysis of various variables (wind speed, external environment temperature, internal temperature, external surface temperature). Paris A et al. 6) measured the insulation performance value of building walls by applying infrared camera and ISO 9869-1 diagnostic method for existing house building in Cyprus, and conducted study to determine the wall thermal transmittance coefficient by comparing and analyzing the numerical values of wall insulation obtained during summer and winter seasons through the method proposed by EN standard. Giuliano Dall'O et al.7) also measured the wall insulation performance value of 14 existing buildings located in Milan, Italy, using Infrared (IR) method and Heat Flow Meter (HFM) method. Through this, they analyzed the accuracy and reliability of the measurement method, and conducted diagnostic method verification study by analyzing the absolute deviation error rate according to the airflow velocity. Sophie obyn et al. 8) analyzed the influence and error of building heating and cooling derived from various coefficients of building envelope (wall, floor, roof, window) as a study investigated the surface convective thermal transmittance coefficient derivation equation used in the calculation of building heating and cooling load.

In this study, we selected existing deteriorated houses based on the contents of the previous studies, and analyzed the wall insulation performance of building applying Heat Flow Meter method applied standard ISO 9869-1, and ASTR method, which is simple method proposed in this study, and verified the diagnostic method measurement error by comparing and analyzing the above diagnostic methods. In addition, after quantitatively examining and analyzing the parts with the lowest insulation performance of the building wall, we suggested the ways (building renovation, replacement, repair, and insulation work) to improve buildings with efficient energy use by suggesting the ways to improve building energy efficiency. In addition, we analyzed the wall insulation performance before and after construction and the wall age change rate by comparing the field measurements result values with the wall regulation values at the time of completion.

2. Study Method

To carry out this study, the following study methods were applied.

(1) To measure the wall insulation performance of existing deteriorated houses, we applied and analyzed the diagnostic method conducted in previous studies.

(2) We selected for the low-income deteriorated households supported by the energy efficiency treatment program promoted by the government, and performed field measurements by applying the method of ISO 9869-1 and the ASTR method conducted in the previous study.

(3) We analyzed the wall insulation performance through wall U-value measurement results obtained in (2), and analyzed the error rate of precision method and simple method for building wall insulation performance measurement.

(4) We suggested the ways to improve building energy by quantitatively analyzing the poor wall insulation performance in buildings, and analyzed The wall insulation performance before and after construction by improving vulnerable parts (building renovation, replacement, repair, insulation work)

2.1. HFM(Heat Flow Meter) method

ISO 9869-1, international insulation performance field measurement standard, is a diagnostic method with high measurement accuracy when the data measured by field measurement of U-value is quasi-normal state. It is possible to measure the U-value of building exterior wall by applying Heat flux Meter sensor to specific part such as building wall, roof, and floor. However, to measure the insulation performance of wall, there are disadvantages that constraints (prevention of indoor airflow, meteorological condition [Direct sunlight, snow, rain], steady-state condition implementation) is difficult, the measuring equipment is expensive, and the process is complicated. In this study, HFM method was defined as precision diagnosis method and measurement was performed. In this study, we calculated by the average method, wall U-value calculation method, using the value divided the heat flux (W / m2) by the indoor and outdoor air temperature difference measuring more than three days. The insulation properties of the building elements in the steady state are as follows.

$$U = \frac{q}{(T_{ia} - T_{ea})} = \frac{1}{R_T} \quad (1)$$

Here, U is U-value, q is the heat flux(W/m2), Tia is the indoor temperature, Tea is the outdoor temperature, RT is the total thermal resistance, and The U-value was calculated by the average method of Eq. (2).

$$U = \frac{\sum_{j=1}^{n} q_j}{\sum_{j=1}^{n} (T_{iaj} - T_{eaj})} \quad (2)$$

2.2. ASTR(Air-Surface Temperature Ratio) method

The ASTR simple diagnostic method is a research method designed with the assumption that the heat flux flowing from the outdoor to the indoor wall is the same as the heat flux delivered from the indoor air layer to the indoor wall surface when the room is in a normal state. n this study, wall U-value was calculated by applying ASTR method as the diagnostic simple method. In the case of simple method, it is the method to calculate wall U-value by applying indoor and outdoor air temperature, indoor wall surface temperature, and indoor surface thermal transmittance, which is reciprocal value of indoor surface thermal transmittance resistance value. ASTR method is advantageous in that the price of measurable equipment is lower than that of the HFM method, and the measurement method and conditions are simple. However, since there is a disadvantage that the measurement accuracy is low, the measurement error rate was compared with the precision method to verify the measurement accuracy of ASTR method in this study.

$$U = \alpha_i \left[\frac{\sum_{j=1}^{n} (T_{iaj} - T_{sij})}{\sum_{j=1}^{n} (T_{iaj} - T_{eaj})} \right] \quad (3)$$

Here, Tia is the indoor air temperature (℃), Tea is the outdoor air temperature (℃), which are the value applied mean value of the measurement time over 72 hours, and Tsi is the external surface temperature (℃)of envelop, Tsi is the indoor wall surface temperature, and α_i is the wall surface thermal transmittance rate. In this study, we analyzed the measurement error rate by comparing the result of applying the indoor wall surface total thermal transmittance rate 9W/(m2·K), which is the reciprocal value of the indoor surface thermal transmittance resistance value, proposed in the Building Energy Saving Design Standard(2016) applied in the previous studies, and the result of applying indoor surface thermal transmittance rate 7.69W/(m2·K), which is the reciprocal value of the indoor surface thermal transmittance resistance value 0.13, proposed in standard ISO 6946 applied in this study.

3. Existing Deteriorated Houses Field Measurement

3.1. Building for Study

As the buildings for this study, we selected 4 households which were most similar to the low-income deteriorated houses standard model analyzed by statistical analysis of direction, completion year, the number of rooms, and floor area occupying the highest ratio of the approximately 180,000 families selected and supported as energy efficiency treatment program of energy low-income class performed from 2009 to 2014. Each households is located in Seoul, Gangneung, Gyeongju, and Pohang, and the building was built between 1978 and 1991, and all four households was over 25 years old. As for the field measurement period, the wall insulation performance was measured for one month from December 1, 2015 to December 15 before construction, 2015, and from January 15 to February 1, 2016 after construction.

There were no data related to the wall performance for buildings studied in this study. Therefore, in this study, we set as the default value using the legal basis data of windows and walls at the time of completion, and analyzed the aged deterioration rate by comparing the legal reference value at the time of completion and the field measurement result. In case of Seoul (Case A) building whose construction year was in 1989, the central legal standard of the wall facing directly the outside air has 0.58 W/(m2·K), and the roof has 0.58 W/(m2·K). In case of Gangneung (Case B), Gyeongju (Case C), and Pohang (Case D) buildings, whose construction year were in 1978, 1979, and 1991, the southern legal standards of the wall facing directly the outside air has U-value of 1.05W/(m2·K) and roof has 1.05 W/(m2·K). For the window, houses located in Seoul were applied with general duplex window with wooden frame, and the legal standard of 3.1 W/(m2·K), the houses located in Gangneung and Pohang were applied with aluminum frame of 6.6 W/(m2·K), and houses located in Gyeongju were applied with wooden frames window of 6.6 W/(m2·K). Building overview, performance summary information by building type and the building foreground and drawing information are shown in Table 1 and Figure 1.

3.2. Field Diagnostic Equipment

The details of equipment used to measure the insulation performance of the walls of buildings in this study are shown in Table 2.

Heat flux (q) and the indoor and outdoor walls air temperature (Tia, Tea) was measured by using the measurement method of ISO 9869-1 (HFM method) defined insulation performance diagnosis precision method. Each HFM sensor used sensor of G company which secured the measurement accuracy and reliability, and the insulation performance of the wall was continuously measured for one week. To measure the ASTR method defined by the field measurement simple method, T-type thermocouple, hygrometer, and 4-channel data logger were used and indoor wall surface temperature(Tsi), the outdoor temperature data (Tea), and the indoor wall air temperature (Tia) were obtained.

Table 1. Overview of Building

	Case A	Case B	Case C	Case D
Location	Seoul	Gangreung	Gyeongju	Pohang
Completion Date	1989	1979	1991	1978
Floor Area	34.97 m^2	33.52 m^2	51.22 m^2	41.34 m^2
Height	2.3 m	2.4 m	2.25 m	2.3 m
Orientation	West	South	South	South
Exterior wall (W1) [W/(m^2·K)]	0.58	1.05	0.58	1.05
Exterior Roof (R1) [W/(m^2·K)]	0.58	1.05	0.58	1.05
Window (G1) [W/(m^2·K)]	3.1 (Wood double window)	6.6 (Aluminum clear window)	6.6 (Wood clear window)	6.6 (Aluminum clear window)

Fig. 1. Building overview

Table 2. Overview of the in-situ measuring equipment

Index	Classification		Accuracy	
Heat flow Meter method (G Inc.)	Model	GreenTEG_Heat flux Kit	Heat Flux (W/m^2) < 0.22	Temperature (℃) ±0.5
	Quantity	4 EA		
ASTR method	Model	HOBO 4-ch Data Logger + T-type Thermocouples	Time ±1 minute per month	Temperature (℃) ±0.5
	Quantity	4 EA		
Air Temperature & humidity	Model	Thermo Recorder TR-72wf	Humidity (%) ±5 RH	Temperature (℃) ±0.5
	Quantity	4 EA		

3.3. Measurement Location

The installation location of the equipment to measure the building insulation performance acquired data by measuring the temperature and humidity for wall 4 points by direction wall and each zone. The room temperature and humidity were measured by installing TR-72wf thermo-hygrometer for each room, and the indoor and outdoor surface temperature of the wall and wall surface air temperature were measured by installing T-type thermocouple and Heat Flow meter sensor at four points by each direction. Among the buildings in this study, the measurement location for measuring wall insulation performance of Case D is shown in Figure 2. Case A, B, and C are also installed in the indoor side walls (east, west, south, and north) at points ① to ④, which are the same positions as Case D, and to measure the indoor / outdoor temperature difference, T-type thermocouple was installed at each measurement point on each wall to acquire data. At points ⑤ to ⑨, data were acquired by using the hygrometer equipment to measure indoor and outdoor temperature and humidity. The measuring equipment and photograph are shown in Figure 3.

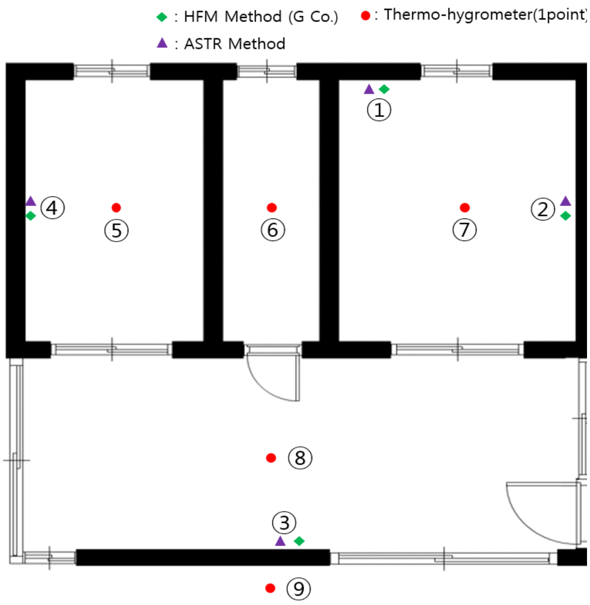

Fig. 2. In-situ measurement point(Case D)

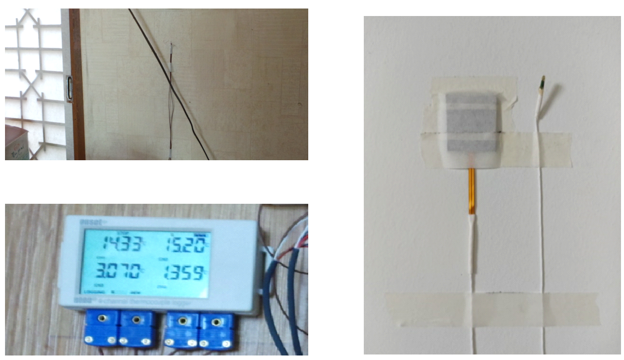

Fig. 3. In-situ measurement experiment(ASTR & HFM method)

Table 3. Measurement results before wall insulation (2015.12.01.~2015.12.15., a.m 01:00~06:00, Measurement interval : 1min)

(n = 903)			W1 (East)	W1 (West)	W1 (South)	W1 (North)
Seoul	U_{HFM} [W/(m²·K)], $(\bar{x}\pm\sigma)$		**0.902 ± 0.0230**	0.881 ± 0.0221	-	**0.909 ± 0.0232**
	U_{ASTR} [W/(m²·K)] $(\bar{x}\pm\sigma)$	α_i : 9 W/(m²·K)	**1.032 ± 0.0363**	1.008 ± 0.0369	-	**1.039 ± 0.0367**
		α_i : 7.69 W/(m²·K)	**0.882 ± 0.0340**	0.861 ± 0.0345	-	**0.888 ± 0.0343**
	Error factor (%)	α_i : 9 W/(m²·K)	-14.44	-14.38	-	-14.33
		α_i : 7.69 W/(m²·K)	2.22	2.27	-	2.31
Gangreung	U_{HFM} [W/(m²·K)], $(\bar{x}\pm\sigma)$		**1.789 ± 0.0411**	1.613 ± 0.0394	**2.038 ± 0.0844**	-
	U_{ASTR} [W/(m²·K)]	α_i : 9 W/(m²·K)	**1.946 ± 0.0661**	1.950 ± 0.0608	**2.471 ± 0.0927**	-
		α_i : 7.69 W/(m²·K)	**1.733 ± 0.0564**	1.666 ± 0.0519	**2.111 ± 0.0792**	-
	Error factor (%)	α_i : 9 W/(m²·K)	-13.37	-20.36	-21.23	-
		α_i : 7.69 W/(m²·K)	3.13	-3.29	-3.58	-
Gyeongju	U_{HFM} [W/(m²·K)], $(\bar{x}\pm\sigma)$		0.979 ± 0.0303	**1.004 ± 0.0323**	**1.094 ± 0.0301**	0.934 ± 0.0308
	U_{ASTR} [W/(m²·K)] $(\bar{x}\pm\sigma)$	α_i : 9 W/(m²·K)	1.106 ± 0.0420	**1.277 ± 0.0425**	**1.206 ± 0.0428**	1.116 ± 0.0426
		α_i : 7.69 W/(m²·K)	0.945 ± 0.0406	**1.091 ± 0.0410**	**1.031 ± 0.0403**	0.954 ± 0.0410
	Error factor (%)	α_i : 9 W/(m²·K)	-12.97	-27.18	-10.23	-19.48
		α_i : 7.69 W/(m²·K)	3.47	-8.67	5.75	-2.14
Pohang	U_{HFM} [W/(m²·K)], $(\bar{x}\pm\sigma)$		1.644 ± 0.0403	1.558 ± 0.0703	**1.699 ± 0.0603**	**1.738 ± 0.0938**
	U_{ASTR} [W/(m²·K)] $(\bar{x}\pm\sigma)$	α_i : 9 W/(m²·K)	2.007 ± 0.0992	1.738 ± 0.0987	**2.080 ± 0.1003**	**2.157 ± 0.1021**
		α_i : 7.69 W/(m²·K)	1.715 ± 0.0777	1.485 ± 0.0679	**1.777 ± 0.0807**	**1.843 ± 0.0872**
	Error factor (%)	α_i : 9 W/(m²·K)	-22.09	-11.55	-22.41	-12.37
		α_i : 7.69 W/(m²·K)	-4.32	4.68	-4.59	3.97

3.4. Measurement Process and Conditions

To measure the insulation performance of buildings of this study, the following measurement process was applied and the mea surement conditions were established. First, we visited the field and visually confirmed the condition of house, and confirmed the condition of wall by direction by using the thermal imaging equipment (refer to ISO 6781 standard). Next, after identifying the position where the temperature gradient of the indoor wall temperature of each wall is constant, we performed the measurement by attaching heat flux meter sensor and T-type thermocouple at the location of wall (center of the wall) using thermally conductive adhesive tape. And the HFM sensor was measured by avoiding the location where the cracked wall, the corner part where the heat bridge part is generated, and the wall temperature gradient is not constant. In addition, we performed the measurement by setting conditions that could not operate the device such as fan, ventilating fan, and hood that can generate an airflow in the entire indoor. In addition, we performed the measurement by selecting the region where the heat flow sensor is not directly exposed to direct sunlight, and analyzed by extracting the data of the time zone from 1:00 am to 5:00 am not receiving sunlight. This is a method of calculating U-value through the difference between the indoor temperature and the outdoor temperature, the difference between the indoor temperature and the wall surface temperature, and the wall surface heat flux information in both HFM method and ASTR method. Therefore, because there arises a problem that the measurement error rate increases when the outside temperature changes greatly in winter, the morning time, which is the time interval with the smallest temperature variation, was selected and measured to implement the experimental conditions in a quasi-steady state. The temperature variation range was analyzed by time-series data within the temperature difference range of about 0.1 to 1.2 degrees per hour, and at least 3 days (72 hours or more) as described in ISO 9869-1 was performed. The indoor temperature was set at 20~22℃ and the difference of indoor and outdoor temperature was maintained at 15 degrees or more.

4. Field Measurement Result

This study quantitatively analyzed the wall insulation performance by applying the highly accurate insulation performance field measurement method to analyze the insulation performance of the target building wall. The present wall insulation performance of building through the research method presented in Section 2 was analyzed by applying the precision method and the simple method. In addition, long-term insulation performance and aged change were analyzed by comparative analysis of U-value of designed standard at the time of completion and U-value derived from the measurement of the wall after 25 years. Finally, to analyze the measurement error ratio of measurement precision method and simple method, the measurement error rate was analyzed by comparative analysis of the result of applying the domestic total thermal transmittance rate (α_i) 9W/(m2·K)value and the result of applying indoor surface thermal transmittance rate (α_i) 7.69W/(m2·K) value, ISO6946 standard in this study. The wall insulation performance before insulation work was measured for

Table 4. Measurement results after wall insulation (2016.01.15.~2016.02.01., a.m 01:00~06:00, Measurement interval : 1min)

(n = 903)			W1 (East)	W1 (West)	W1 (South)	W1 (North)
Seoul	Design U-value [W/(m²·K)]		0.474	-	-	0.496
	U_{HFM} [W/(m²·K)], $(\overline{x}\pm\sigma)$		0.464 ± 0.0225	-	-	0.508 ± 0.0203
	U_{ASTR} [W/(m²·K)] $(\overline{x}\pm\sigma)$	α_i : 9 W/(m²·K)	0.588 ± 0.0328	-	-	0.630 ± 0.0288
		α_i : 7.69 W/(m²·K)	0.502 ± 0.0291	-	-	0.538 ± 0.0237
	Error factor (%)	α_i : 9 W/(m²·K)	-26.62	-	-	-23.95
		α_i : 7.69 W/(m²·K)	-8.19	-	-	-5.91
Gangreung	Design U-value [W/(m²·K)]		0.781	-	0.971	-
	U_{HFM} [W/(m²·K)], $(\overline{x}\pm\sigma)$		0.827 ± 0.0511	-	1.013 ± 0.0299	-
	U_{ASTR} [W/(m²·K)] $(\overline{x}\pm\sigma)$	α_i : 9 W/(m²·K)	0.935 ± 0.0761	-	1.237 ± 0.0387	-
		α_i : 7.69 W/(m²·K)	0.799 ± 0.0864	-	1.057 ± 0.0489	-
	Error factor (%)	α_i : 9 W/(m²·K)	-13.07	-	-22.12	-
		α_i : 7.69 W/(m²·K)	3.39	-	-4.34	-
Gyeongju	Design U-value [W/(m²·K)]		-	0.501	0.573	-
	U_{HFM} [W/(m²·K)], $(\overline{x}\pm\sigma)$		-	0.536 ± 0.0383	0.609 ± 0.0320	-
	U_{ASTR} [W/(m²·K)] $(\overline{x}\pm\sigma)$	α_i : 9 W/(m²·K)	-	0.595 ± 0.0422	0.735 ± 0.0482	-
		α_i : 7.69 W/(m²·K)	-	0.508 ± 0.0389	0.628 ± 0.0442	-
	Error factor (%)	α_i : 9 W/(m²·K)	-	-10.92	-20.69	-
		α_i : 7.69 W/(m²·K)	-	5.22	-3.12	-
Pohang	Design U-value [W/(m²·K)]		-	-	0.759	0.935
	U_{HFM} [W/(m²·K)], $(\overline{x}\pm\sigma)$		-	-	0.899 ± 0.0803	1.015 ± 0.0938
	U_{ASTR} [W/(m²·K)] $(\overline{x}\pm\sigma)$	α_i : 9 W/(m²·K)	-	-	1.109 ± 0.0903	1.291 ± 0.1021
		α_i : 7.69 W/(m²·K)	-	-	0.948 ± 0.0907	1.103 ± 0.0872
	Error factor (%)	α_i : 9 W/(m²·K)	-	-	-23.41	-27.18
		α_i : 7.69 W/(m²·K)	-	-	-5.45	-8.67

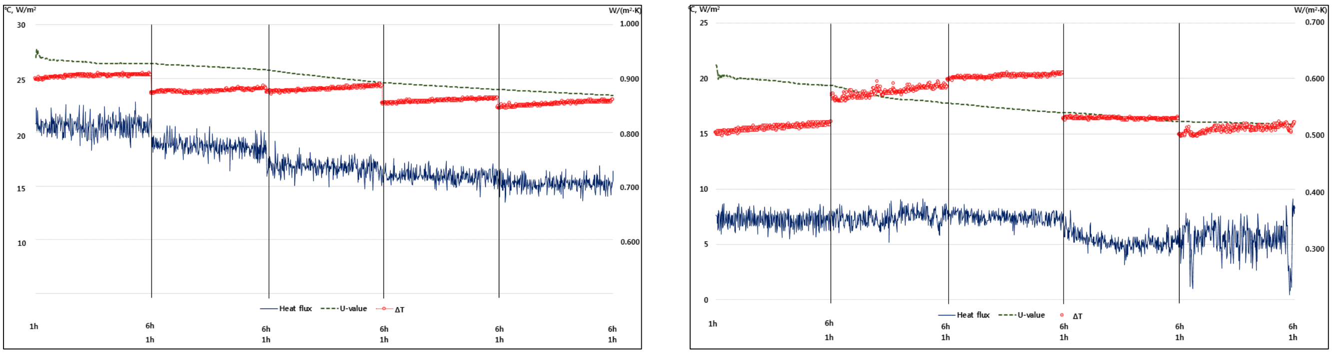

Fig 4. Seoul existing deteriorated houses measured value(Heat Flux[Bottom line], ⊿T[Circle marking], and U-value(Dotted line) trends for the envelope components investigated.

about 2 weeks from December 1, 2015 to December 15, and the data of the time zone (a.m 01: 00 ~ 06: 00) not affected by solar radiation on the wall was obtained and analyzed. The results are shown in Table 3.

As measurement result, the wall U-value of Seoul households derived through HFM method defined by the precision method was analyzed as 0.909 W/(m2·K) in the north, 0.902 W/(m2·K) in the east and 0.881 W/(m2·K) in the south. It was analyzed that the insulation performance of about 50 ~ 56% was lower compared to the legal U-value at the time of completion, and the deviation of measurement error was about 2.6%. The wall U-value of Gangneung households was measured as 1.789 W/(m2·K) in the east, 1.613 W/(m2·K) in the west wall and 2.038 W/(m2·K) in the south. It was analyzed that the insulation performance of about 34 ~ 48% was lower compared to the legal U-value at the time of completion, and the standard deviation of measurement error was about 2.4~4.14%. Third, the wall U-value of Gyeongju households was measured as 0.979 W/(m2·K) in the east wall, 1.004 W/(m2·K) in the west, 1.094 W/(m2·K) in the south, and 0.934W/(m2·K) in the north. It was analyzed that the insulation performance of about 40~46% was lower compared to the legal U-value at the time of completion, and the deviation of measurement error was about 2.75~3.21%. Finally, the wall U-value of Pohang households was measured as 1.644 W/(m2·K) in the east, 1.558 W/(m2·K) in the west, and 1.738W/(m2·K) in the north. It was analyzed that the insulation performance of about 32~39% was lower compared to the legal U-value at the time of completion. As a analysis result through ASTR method defined by simple method, the surface thermal transmittance rate were compared and analyzed by applying the value of 9W/(m2•K) proposed in the Energy Saving

Design Standard of domestic buildings and the value of 7.69W/(m2•K) proposed in ISO 6946 standard. The measurement error rate was analyzed by comparing the wall performance diagnosed by the precision HFM method and the wall performance and the results diagnosed by the simple ASTR method. In case of wall performance measured by Seoul households, the error rate was about 13.22% when the domestic standard was applied, and 3.25% when the ISO standard was applied. In case of wall performance measured by Gangneung households, the measurement error rate was about 17.04% when the domestic standard was applied, and 1.3% when the ISO standard was applied. In case of wall performance measured by Gyeongju households, the measurement error rate was about 17.3% when the domestic standard was applied, and 0.25% when the ISO standard was applied. Finally, the Pohang buildings showed the error rate of 20.23% in domestic standard and 2.73% in ISO standard. In the case of the measurement error standard deviation, Seoul households showed error rate of 3.5 ~ 4.01% in domestic standard and 3.8% in ISO standard, and the measurement error standard deviation of Gangneung households showed 4.7~6.9% in domestic standard and 3~3.8% in ISO standard. The measurement error deviation of Gyeongju households was 3.5~3.8% in domestic standard and 3.9~4.3% in ISO standard, and the measurement error deviation of Pohang households howed 4.7~5.6% in domestic standard and 4.5~4.7% in ISO standard. As a result of analyzing wall insulation performance before construction through the simple diagnosis method, it was analyzed that the measurement result the error rate decreased when applied the surface thermal transmittance rate standard specified in ISO 6946 compared to the measurement result value applied to the domestic surface thermal transmittance rate standard. The wall insulation performance after construction was measured for about two weeks from January 15, 2016 to February 1, 2016, and the results are shown in Table 4. Typically, the heat flux data before and after construction of Seoul households is shown in Figure 4. In this study, the wall insulation performance was analyzed by performing the actual construction on the site where the wall insulation performance is weak based on the measurement results before the wall insulation. Seoul households carried out the wall insulation work in the east and north wall, Gangneung households in the east and south wall, Gyeongju households in the west and south wall, Pohang households in the south and north wall. The insulated wall repair work was carried out using 20 ~ 30mm extrusion method insulating plate No. 1 as insulation material. As construction method, the insulation material was tightly adhered to the wall, and then airtightly filled with urethane foam between the plate materials, and after each frame was formed, it was finished with one gypsum board. As a result of measurement after construction, the results of Seoul households derived through the HFM method, the east wall U-value was 0.464 W/(m2·K) and the north wall, 0.508 W/(m2·K). This result showed that the insulation performance of the east wall was improved by 48.6% and that of the north wall was improved by 44% compared to before construction. Gangreung households were analyzed at 0.827W(m2·K) in the east and 1.013W(m2·K) in the south. and the insulation performance of east wall was improved by 53.8% and south wall was improved by 50.3% compared to before construction. Gyeongju households was 0.536W /(m2·K) in the west wall and 0.609W/(m2·K) in the south wall of construction, and insulation performance of east wall was improved by 44.3% and south wall was improved by 46.61% compared to before construction. Finally, Pohang residence showed measurement result of 0.899/(m2·K) in the south and 1.738/(m2·K) in the north. and insulation performance was improved by 47.1% in the south wall and was improved by 41.6% in the north wall. As a result of analyzing the results measured by UHFM, which is a precise diagnosis method, using the standard deviation, the measurement error standard deviation showed measurement error rate of about 3.99~7.2 %, and the measurement error standard deviation of UASTR showed about 4.5 ~ 9.7% in domestic standard and 5.8 ~ 8.8% in ISO standard, and both HFM and ASTR methods showed a measurement deviation error rate of less than 10%.

5. Conclusion

In this study, we carried out to quantitatively analyze wall insulation performance directly facing the outside air in the field for the energy performance diagnosis of the existing deteriorated houses. We analyzed the wall insulation performance for existing deteriorated houses of wall part of building wall by applying HFM method, which is precision diagnosis method, and ASTR method, which is simple method, and through this, could quantitatively analyze the insulation performance and the aging change rate of the wall over 25 years. Also, we verified the more reliable field measurement method by reducing the error rate range of the precision method and the simple method proposed in the previous study by analyzing the measurement error rate of wall insulation performance according to measurement method. And, we selected the walls which have weak wall insulation performance through diagnosis and carried out insulation works, and analyzed whether wall insulation performance has improved really through measurement.

(1) We analyzed the long-term insulation performance of the wall after 25 years through comparison of U-value obtained from the legal design standard at the time of completion and U-value

derived from field measurements. As a result of the analysis, it was analyzed that the average insulation performance of Seoul households was reduced by about 54%, and the insulation performance of Gangneung and Gyeongju households was reduced by 72%. Finally, it was analyzed that the wall insulation performance in Pohang households was reduced by about 58%.

(2) We visited the building site to analyze the wall insulation performance quantitatively by the wall U-value measurement, and constructed the wall insulation by diagnosing the wall with poor insulation performance. As a result of the analysis, the insulation performance of the east and the north walls of Seoul households was improved by about 46.3%, and the insulation performance of the east and south walls of Gangneung households was improved by about 49%. The insulation performance of west and south walls of Gyeongju households was improved by about 43% and the insulation performance of the south and north walls of Pohang households was improved by about 42.3%.

(3) We analyzed the measurement error rates of HFM method and ASTR method. In the case of the ASTR diagnosis method, the measurement error rate was analyzed by comparing the result value obtained by applying the indoor surface thermal transmittance rate 9W/(m2·K), which is the indoor wall surface thermal transmittance resistance reciprocal value presented in the Energy Saving Design Standard (2016), and result value obtained by applying the indoor wall surface thermal transmittance rate 7.69W/(m2·K) value referring to ISO 6946 standard in this study. As a result of comparing the error rate with HFM method, which is a precise diagnosis method applying domestic standards, measurement error rate showed high error range of about minimum 10.23%, maximum 27.18%. As a result of analyzing error rate compared with the HFM method when the ISO standard was applied, measurement error rate showed about minimum 2.14%, maximum 8.67%. Therefore, in this study, the reliability of measurement diagnosis method could be secured through indoor surface thermal transmittance rate coefficient adjustment.

(4) In this study, we could obtain and analyze the quantitative numerical data of wall insulation performance of building with aged change by applying the field measurement method of building, and analyze the level of wall insulation performance of actual existing deteriorated houses by suggesting the ways to improve the part that the wall insulation performance was poor to buildings that can use energy effectively through the field measurement method. As a result of analysis, the insulation performance of Seoul households was improved by 44~48.6% compared to before and after the construction, and the insulation performance of Gangreung households was improved by 50.3 ~ 53.8%. The wall insulation performance of Gyeongju households was improved by 44.3~46.61% and the insulation performance of Pohang households was improved by 41.6~47.1%.

As a further study, we also plan to carry out additional significance analysis according to the diagnostic method through sensitivity analysis and statistical analysis on wall insulation performance according to various variables (wind speed, external environment temperature, internal temperature, external surface temperature, measurement time) of field measurement evaluation by analyzing the wall insulation performance diagnosis data additionally measured in the field. In addition, since the study on the accurate indoor surface thermal transmittance rate is insufficient in Korea, it is thought that a further study is needed to diagnose wall thermal performance through numerical correction by measuring and analyzing the surface wall thermal transmittance rate suitable for various variables and domestic climate, environment, and property.

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