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Analysis of the Heating Energy Demand of a New-constructed Single- family House in Korea with Criteria of PHPP

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Abstract

The green-house gas emission of the building industry in Korea is up to 24%. The Korean government makes an effort to reduce the green-house gas emission by planning the compulsory energy saving in buildings. The target of energy saving in residential building can be accomplished by offering the zero energy houses until 2025. In this situation, the passive house is up for discussion as one of the best solution to accomplish the building energy saving plan.

In this paper, the heating energy demand of a newly constructed single-family house, general residential type in Korea, was analyzed as a reference building by simulation method. And the results were compared with the passive house criteria (PHPP).

The results indicated that the heating energy demand of the reference building was 56.05 $kWh/m^2 \cdot year$. Four times more heating energy is required in a newly constructed single-family house in Korea compared to the that of passive house (15 $kWh/m^2 \cdot year$).

In this paper, the reason why the heating energy demand of the reference building is higher than the passive house was discussed. Also, the strategies for reducing the heating energy demand of the reference building were analyzed.

Keywords – PHPP, Heating energy demand, New constructed single-family house

1. Introduction

The building energy consumption is up to 21% of the total energy consumption in Korea, and the growth rates are faster than other industry [1]. In order to lower the energy consumption and green-house gas emission in building industry, the Korean government has established the energy roadmap. According to the roadmap, the energy saving rate of new residential buildings should be reached about 60% until 2017. From 2025, new residential buildings should be constructed as zero energy building and non-residential buildings should have an energy saving rate of 60% [2] (see Table 1).

In this paper, the heating energy consumptions of new-constructed single-family house in Korea were analyzed and the results were compared with the passive house criteria (PHPP) [3]. The passive house is a building standard that is energy efficient, comfortable and affordable at the same time [4].

The purpose of this study is to develop the energy saving strategies for raising the energy efficiency of the newly constructed single-family house in Korea at the same level of the passive house.

Table 1. National building energy saving roadmap in Korea[2]

Year	2009	2012	2017	2025
Building energy efficiency category	Energy intensive house	Low energy house	Passive house	Zero energy house
Energy saving rate residential buildings	0%	30%	60%	100%
Energy saving rate non-residential buildings	0%	15%	30%	60%
Specific reduction factors	0% reduction of heating and cooling energy demand	50% reduction of heating and cooling energy demand	90% reduction of heating and cooling energy demand	90% reduction of heating and cooling energy demand
Applied improvement measures (building envelope and services engineering system)	7 cm thermal insulation, double glazing, high efficiency boiler	15 cm thermal insulation, triple glazing, mechanical ventilation with heat recovery	25 cm thermal insulation, high efficiency windows, LED lighting	25 cm thermal insulation, high efficiency windows, LED lighting, renewable energy production

2. Method

2.1 Analyzed house

The reference building is a general single-family house that is located in Yangpyeung, nearby Seoul in Korea. This building was constructed recently and designed as energy efficient building and represents the latest trend in Korea. Nowadays, as the energy saving in building industry becomes more important, the interest for low-energy residential building is growing among the people in Korea. A large number of the residential buildings in Korea are being constructed with energy saving design. The information about the reference building are shown in Fig.1 and Table 2

Fig. 1 Photo of the reference house

Table 2. Reference building information

<table>
<tr><td rowspan="6">Building information</td><td>Location</td><td>Yangpyeong, South Korea</td></tr>
<tr><td>Building type</td><td>Single-family house</td></tr>
<tr><td>Site area</td><td>396.7 m^2</td></tr>
<tr><td>Building to land area</td><td>68.77 m^2</td></tr>
<tr><td>Total floor area</td><td>177.98 m^2</td></tr>
<tr><td>Building size</td><td>2nd ground floor, basement</td></tr>
<tr><td rowspan="5">Construction and materials (W/ m^{2}K)</td><td>Exterior wall</td><td>0.160</td></tr>
<tr><td>Inner wall</td><td>0.175</td></tr>
<tr><td>Ground floor</td><td>0.171</td></tr>
<tr><td>1st floor</td><td>0.114</td></tr>
<tr><td>Roof</td><td>0.146</td></tr>
</table>

	Window	Frame	1.59
		Glass	2.71
		SHGC(-)	0.47

2.2 Simulation

The heating energy demand of the reference building was analyzed by Energyplus. Historic Seoul weather data (EPW) published by Korean Solar Energy Society [5] was used for the energy simulation. There is no specific performance standard about single-family house in Korea. The energy saving design standards of Korea, that is the Building Design Criteria for Energy Saving (BDCES), is applied for the multi-residential and commercial buildings. However, the thermal insulation performance of the reference building was strengthened compared with the Building Design Criteria for Energy Saving (BDCES) in South Korea [6] according to the latest construction trend for single family house in Korea.

Indoor thermal designed condition was followed by BDCES in South Korea [7]. The internal heat gain level (lighting, equipment, people) defined by PHPP was used [8] and the schedule for internal heat gain level was applied the values suggested by ASHRAE [9]. The infiltration rate was based on the measurements results for the newly constructed single-family houses in Korea [10]. Ventilation system was not equipped in reference house because the ventilation system is not compulsory in case of the single-family houses in Korea. The simulation conditions are shown in Table 3

Table 3. Simulation conditions

		Summer	Winter
Designed indoor thermal condition[5]	Dry-bulb temperature(℃)	26	20
	RH(%)	50	50
Internal heat gain[8]	-Lighting (h/W/ m^2) : 5 / 5.5 [11] -Equipment (Wh/ m^2 per day) : 52 -People (Wh/ m^2 per day) : 53		
Infiltration[10]	1.0 ACH at 50 Pa		
System	-Radiant floor heating -Type : Gas fired -Efficiency : 83%		

The analysis was accomplished in two phases. At first, the heating energy demand of the reference single-family house was compared with the PHPP standard. Second, the annual heating energy demands of the reference single family house were analyzed in a diverse energy saving strategies (Table 4).

Table 4. Simulation cases

	Thermal insulation (W/ m^2K)	Infiltration of Air-tightness (ACH at 50 Pa)	Ventilation	Heat exchanger
Case 1	See Table 2.	1.0[10]	Without	Without
Case 2-1		0.8[12]		
Case 2-2		0.6[13]		
Case 3-1		0	0.5 ac/h[14] (203 m^3/h)	Without
Case 3-2		0		With[15] (cooling-efficiency of heat transfer : 45% heating-efficiency of heat transfer : 70%)
Case 4-1		0	120 m^3/h[16] (0.295 ac/h)	Without
Case 4-2				With[17] (efficiency of heat transfer : 95-75%, Efficiency of sensible heating over : 85%, Consumption of electrical power : 0.45 W/m^2h)

Case 1 represented the current state of the reference single-family house in Korea. Case 2 corresponded to a building in which the air-tightness level was improved compared to the Case 1. Case 3 corresponded to a building in which the ventilation system with or without heat-exchanger was installed based on the Korea building code [14, 15]. Case 4 represented the case which the ventilation system with or without heat-exchanger was installed based on the PHPP standard [16, 17]. Infiltration is not assumed when positive air pressure is assumed owing to the installation of ventilation system, such as in Case 3 and Case 4 [18].

3. Results

3.1 Heating energy demand of the reference house

The reference building is equipped with a radiant floor heating system for heating. According to the PHPP's guideline, the peak heating load of the passive house should be below 10 W/m^2. The peak heating load of the reference house was 74.37 W/m^2, 7.4

times higher than that of the PHPP. The peak heating load of the reference house was caused by conduction and infiltration. Especially, the infiltration load was quite high.

The annual heating energy demand suggested by PHPP standard is below 15 kWh/m^2·year. The annual heating energy demand of the reference house was 56.05 kWh/m^2·year, 3.6 times higher than that of the PHPP. Even though, the thermal performance of the envelope in the reference house was improved compared to the currently envelope design standard of Korea, the heating energy demand of the reference building was quite high compared to the passive house.

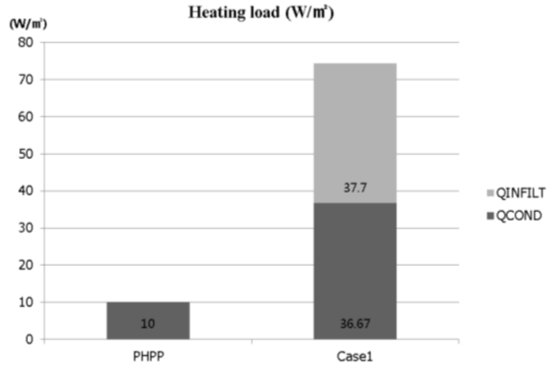

Fig. 2 Peak heating load

3.2 Effect of the Air-tightness and Ventilation system on Annual Heating energy Consumption.

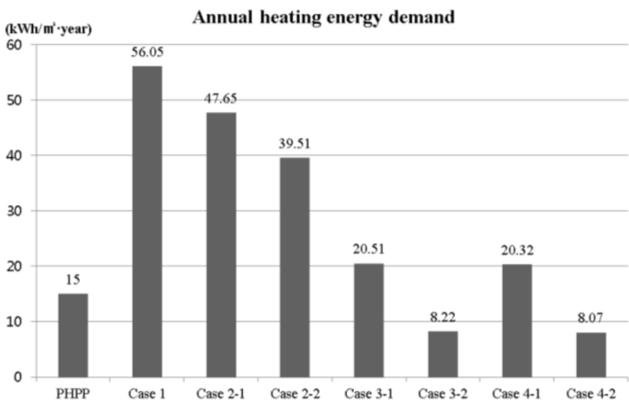

Fig. 3 Annual heating energy demand

The effect of annual heating energy demand of the reference house with the air-tightness and ventilation system was analyzed (Fig. 3).

The annual heating energy consumption decreased with a decrease of infiltration rate in Case 2. Also, the annual heating energy demand dramatically decreased in accordance with installation of ventilation system with heat exchanger in Case 3. The minimum heating energy demand was accomplished in the reference house when the ventilation system with heat-exchanger was installed based on the PHPP. The effect of ventilation system with heat exchanger showed the highest ratio of heating energy saving among the analyzed cases in this study. These results indicated that the annual heating energy demand of the single-family house in Korea can be reduced at a half to same level of the passive house by strengthening the air-tightness and installation of an energy recovery ventilator.

4. Conclusion

In this paper, the heating energy demand of a newly constructed single-family house, general residential type in Korea, was analyzed as a reference house by simulation method. And the results were compared with the passive house criteria (PHPP).

The results showed that the annual heating energy demand of the reference house was about 3.6 times higher than that of the passive house. Also, the peak heating load was about 7.4 times higher than that of the passive house.

The annual heating energy demand proportionally decreased when the air-tightness of the reference building was improved. Energy recovery ventilator showed the highest energy saving performance among the analyzed cases in this study. Also, the annual heating energy demand of the newly constructed single family house in Korea can be reduced at a same level of the passive house by strengthening the air-tightness and installation of an energy recovery ventilator.

The design guideline for air-tightness and energy recovery ventilator should be suggested to accomplish the roadmap of zero energy house in Korea.

Acknowledgment

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