A Study of Design principle and Technology performance applied in Passive House

- Focused on cases of the apartment type of Passive Houses in European -

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Abstract

Recently, the role of the architecture which is corresponding to climate change and saving energy has been important. This study drew factors about design principle, technology performance on passive house, focusing on apartment and multi-family house cases in Europe. The dwelling type of Korea and climate, however, are different from the European styles, and therefore it is necessary to develop energy efficient design, technology and details that is applicable to Korea's apartment. Under this circumstance, this study aims at providing the fundamental data for drawing design principle, technology performance, details applicable to domestic apartment and climate condition for passive house in Korea. Therefore, this case study is intended to explain three topics: strategy, energy performance, and details.

Keywords: Passive House, Passive Design principle, Energy performance

Introduction

Major global conversation topics in the 21st Century would be "climate change" and "energy saving" above all. During the life cycle a building is designed, constructed, and operated, influence of on the environment and the amount of energy consumed relating to the building are enormous indeed. In view that the building sector occupies 30 ~ 40% of the world's energy consumption (IEA: International Energy Agency, 2005) and 45% of the world's CO2 emissions (UNEP, 2007), it is inevitable to develop the design technique and technology that enables to secure health and comfort of the building occupants and save energy as well. Under these international circumstances, the concepts such as Passive House, Self-sufficient House, Zero Energy House, etc. have been developed. Of them, passive house has been actively studied in Germany and Central Europe since the mid 1990s, and more than 8,000 passive houses have been built since then.

Objectives

This Study is aimed at the analysis of design technique, concept, and energy saving technologies of the foreign advanced countries in order to grasp design principle and architectural technology components necessary to suggest optimized energy-saving housing model that can be applied to domestic apartment house in introducing such advanced passive technology and components. In Korea, based on the classification by housing types in 2005, the ratio of apartment house in the entire residences reaches 53%, marking the highest. In order to embody the housing model in ultra energy saving type in the sector of apartment house that occupies a majority of total housing types, the decision on the design variables that influence on the performance of building at the planning phase should be made in compliance with energy performance in accordance with quantitative objective and systematic design guide line rather than the experience of architect or generally known knowledge only. Therefore, the analysis of information and data on the major strategy and performance applied to the foreign advanced ultra energy saving type apartment houses being carried out in this study would be a very important indicator.

Method of Research and Description

As the method of study, passive house research report and apartment house example and reports that were disclosed by Passive Association were collected.

This study is intended to explore the concept of passive house, analyze foreign examples and research data, and finally derive passive design strategy and component technology applied to the design principle of the passive house.

The case study selected is a model passive house (ultra energy saving house) distribution project - European CEPHEUS (Cost Efficient Passive Houses as European Standards) Project aimed at the distribution of passive house, through which a variety of passive house concept was verified and tested. Of them, five CEPHEUS Projects that fall under the apartment type except detached house and five buildings that have been recently completed out of the PHs built since 2001 were selected in addition.

Definition and Performance Standard of Passive

German Passive House Institute(2001) defines passive house as ‘the building that provides pleasant indoor environment in summer and winter without the necessity of traditional mechanical cooling/heating equipment’, which means energy saving to the maximum by minimizing the loss of thermal energy by actively utilizing natural energy. In 1988, Germany Passive House Institute considers less than 15kWh/㎡.year for heating energy and less than

120kWh/㎡.year for total energy consumed by the building including cooling/water heating/electricity (primary energy consumption) as the prerequisite of passive house.

Passiv haus standard was enacted first in 1995, which forms the most basic standard of Passive.

Besides, the design condition required for Germany's passive house is as shown in Table 1.

Table 1. Passive House Performance Standard

Space Heating Demand	≤ 15 kWh/㎡.year
Primary Energy Demand	≤ 120 kWh/㎡.year
Air Tightness	≤ 0.6
Window Frame/Glass Average U-value	6 h-1 @ 50pa
Energy Ventilation Efficiency of Ventilation System ηHR	75%

Passive Design Principle and Integral Design

Passive house maximizes energy saving passive components used by the building, while minimizes the active components such as renewable energy utilized, etc. The energy saving in the building sector is one of the most important parts out of the objectives of passive house. The passive house design principles are first, Super insulation and Design without thermal bridge; second, Heat recovery and Indoor air quality; third, Passive solar gain; fourth, Electric efficiency; and fifth, On-site renewable to be considered.

To meet these passive house standards, integral plan of interaction between superior design and components is important, that is, it is the key to integrate technology and design to accomplish passive house suitable for climate, land, building type, scale of the region where the building is built. In the passive house Institute, they provide PHPP (Passive House Planning Package) as the planning tool that can be used at the energy design stage of Passive House. PHPP is the integral package program under a simple calculation method that helps design the passive house, which principally calculates periodic heat load by applying a special boundary condition by super insulation without normal heating system and adopts Heating Degree Hours based on 20℃ for the standard indoor temperature in its estimation of yearly energy consumptions of the building. When designing passive house, PHPP Software is used for the calculation of Energy Balance.

Analysis of overseas passive house design and energy performance

[Table 2] shows building type, dwelling unit, area, and structure of the passive houses selected in Sweden, Germany, and Austria.
Besides, the characteristic of passive house was explored from two aspects of passive strategy and energy performance of each case.

Table 2. Architectural Overview of Passive Houses

Project Title		Building Type	Dwelling unit	Treated Floor Area(m²)	Construction
01 Germany, Hannover,Kronsberg		Terraced house	32	3,576	Mixed construction (timber wall, roof, prefab con'c core)
02 Germany, Frankfurt, Hessen, St.Jakob		Multy-family house (2002)	19 (A,B Block. 5F)	1,927	Mixed construction. (timber, masonry)
03 Germany, Kassel		Apart ment (1999)	31	3,055	Solid (masonry) + external insulation
04 Austria, Wolfurt		Multy-family house (1999)	10	1,296	Mixed construction (steel skeleton, con' c ceiling, timber wall)
05 Austria, Lodenareal		Apart ment (2009)	361	28,316	Solid (massive construction)
06 Utendorfgass, Vienna		Apart ment (2006)	60	-	Reinforced concrete

07 Austria, Kuchi		Multy-family house (2000)	25	1,798	Mixed construction (steel column, RC slab)
08 Austria, Hallein		Apart ment (2000)	31	2,318	Mixed construction. (steel skeleton, timber)
09 Samer Mosl, Salzburg		Apart ment (2006)	60	-	Timber Construction (prefabricated wall)
10 Sweden, Gothenburg, Hamnhuset		Apart ment (2008)	116 (4~5F)	-	Mixed construction. (wall-con'c, pillar-steel)

Table 3. Major performances of overseas passive houses

CASE		1	2	3	4	5	6	7	8	9	10
Orientation		South	South & East	East & West	South & West	South & East	South	North & East	South & East	North & East	South, East
U-Value	Wall	0.13	0.11	0.13	0.12	0.13	0.13	0.13	0.11	0.11	0.14
	Roof	0.1	0.1	0.11	0.10	0.11	0.1	0.1	0.11	0.11	0.1
	Win dow	0.75	0.8	0.6	0.83	0.85	0.8	0.7	0.7	0.6	-
Heating Energy		14.2	13	17.2	21.4	14.5	14.5	22.9	12.4	12.5	12
Primary Energy		72.1	119.9	133	56.5	112	118	126.6	-	-	60
Airtightness		0.3	0.3	0.35	0.33	0.2	0.4	0.23	0.58	0.46	-
Heat Recovery Efficiency		99%	84%	85%	79%	90%	-	80%	80%	○	82%
Window System		Triple Low-e, Wood AL. Frame	Triple Low-e, G 53%	Triple Low-e, PVC Frame	Triple Argon Gas glass, Super Insulati on frame	Triple Glass	Triple Glass	Triple Glass	Triple Argon Gas glass	Triple Low-e, Wood AL. Frame	Triple Low-e, Wood AL. Frame
Balcony		Separat -ion from external wall -Heat bridge prevent ion	Steel Struc -ture	Separat ion from externa l wall - Heat bridge prevent ion	NO	Preven tion of heat bridge betwee n balcon y and slab	Steel Struc -ture	Steel Struc -ture	Steel Struc -ture	Steel Struc -ture	Heat bridge preventi on
Solar heat/ Photo voltaic system		Collector 126㎡	-	-	Collector 62㎡	Collector 1,050 ㎡	-	Panel 75㎡	Collector 120㎡	Collector 200㎡	Collector 193㎡

Results and Discussion

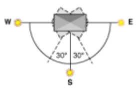
1. Passive Design Technique & Core Technical Components

Design principle and strategy to be considered in passive house design can be divided into Passive components and Active components. Design principle and plan applied in European passive cases are mainly reviewed from the range as below.

○ Passive components

Passive components minimize energy loss by improving the building energy performance.

As far as not cooling the space artificially, there exist the components generating heat only in the building such as sunlight coming in through the window, heat being generated from human body, heat coming from lighting fixture, heat coming out from the operation of electric equipment, etc. It is the passive house and its components to calculate insulation that enables to maintain the heats being generated like this inside the building and airtight condition. The component technologies mainly applied to the cases are as shown in [Fig.1].

Orientation		Maximization of solar radiation gain, minimization of load, south bound arrangement if possible 20% of energy is saved when arranging the orientation to the South
Super Insulation		Reinforcement of insulation by three times based on domestic standard. Heat transmission coefficient: 0.15 W/m2K for building shell, 0.11 W/m^2K for roof
Space Heating		Traditional heating method : replacing into waste heat recovery system by ventilation; Condensing boiler, geo thermal heat pump, etc.
Building Shape		Minimizing Area/Volume Ratio – High Compact form (Compactness Design) Energy saving in consideration of the ratio of lateral to longitudinal length
Triple-glazing window		Low-E triple glazing, Filling Argon gas, High-insulation High performance window frame, Window area south-bound ratio 40~60%, U-value : 0.8W/m^2K

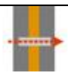
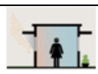
Airtightness		n 50<0.6 ac/h Minimizing the energy loss through air infiltration to secure high air-tightness performance
Heat Recovery		Recovery ratio 75% or more
Thermal Bridge		Air-tightness, window to be installed within shell insulation line, Minimizing the heat exchange around window frame, High-performance insulation, development of details at the junction
Natural ventilation		Building type/wall/opening/inner partition/dual structure/roof ventilation system, etc.
Shading		Southern side awning system for controlling solar heat in summer season, fixed awning, variable awning, awning using trees
Passive Solar Gain		Arrangement at south bound to increase solar radiation gain, hot water supply, power generation Review of location and type of window, consideration of acquisition/loss of sunlight energy depending on window area ratio
Thermal Mass		Applying interior materials such as PCM, etc.

Fig. 1 Extraction of major passive component technologies

○ Active components

Active components produce clean energy through the introduction of new & renewable energy, consisting of solar heat water heating, heating, geothermal, sewage source heat, pellet boiler, wind power generation, fuel cell, co-generation, etc. In the case of solar heat/photovoltaic, it can replace only the energy used by the entire building in part. Therefore, the passive architecture that minimizes the use of energy centered on Europe came to emerge. The followings shown in [Fig. 2] are the active components applied to the case of passive in Europe;

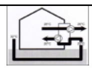
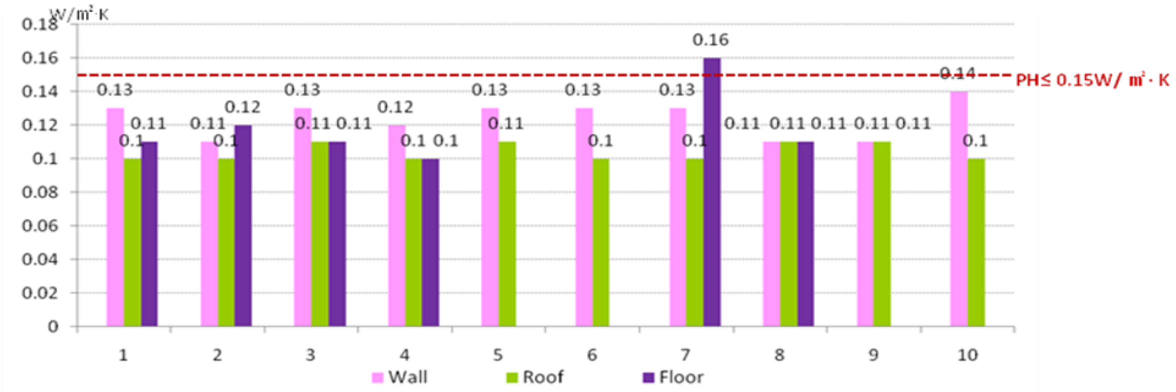
New/Renewable Energy		New/renewable energy (solar heat, photovoltaic, biomass, wind power, etc.)
Geo thermal Heating & Cooling System		Geo thermal Heating & Cooling System - Outdoor air by geo heat using under ground duct, preheating, pre-cooling
Pellet Boiler		Heating/Water Heating System / Co-Generation System

Fig. 2 Major Active Component Technology

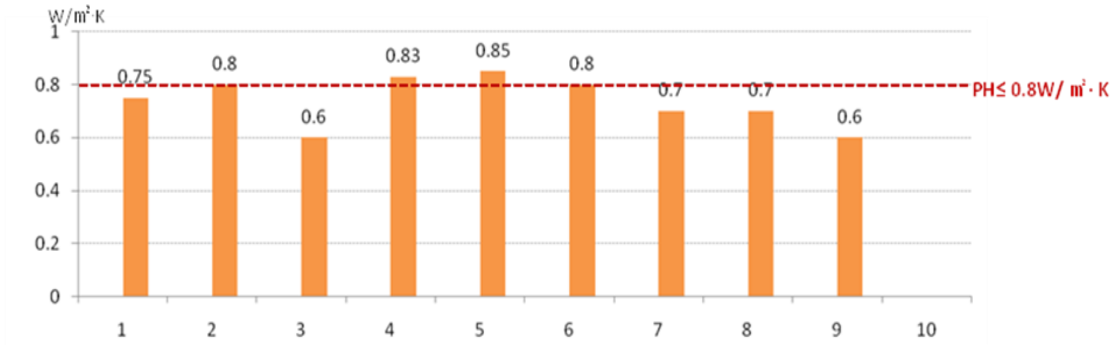
2. Application of Technical Performance

[Fig. 3] is the energy performance level accomplished in each case from which the range of technical performance implemented to the actual passive house can be found.

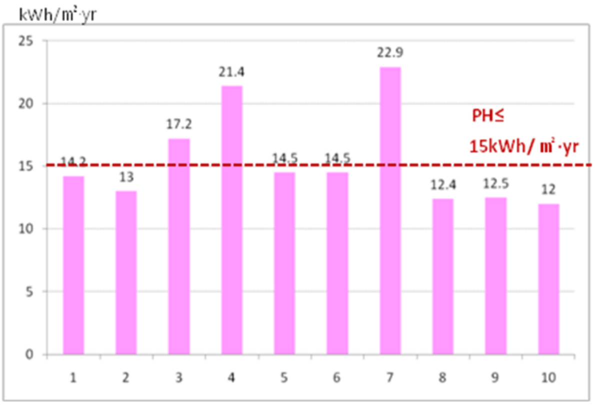
That is, several components of the selected cases exceeds the performance conditions of passive house, but most of them meet the performance within the range of technical solutions suggested by Promotion of European Passive Houses (PEP) in accomplishing Passive House.



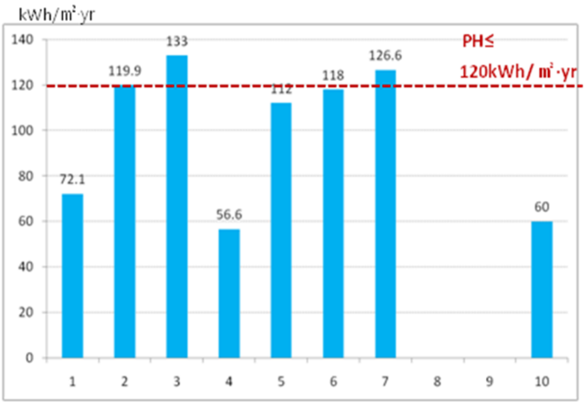
[U-Value - Wall/Roof/Floor]



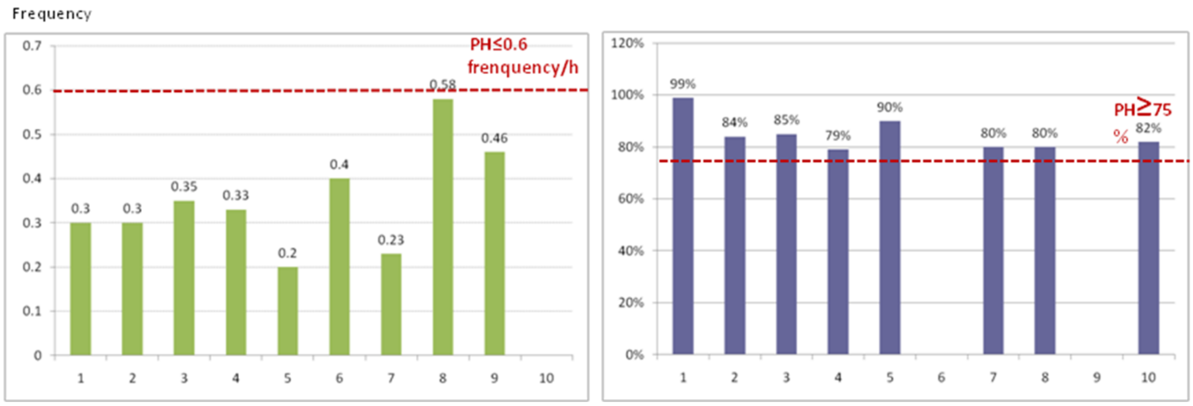
[U-Value - Window]



[Heating Energy Requirement]



[Primary Energy Requirement]



[Frequency of ventilation] [Heat exchanger efficiency]

Fig. 3 Performances of Overseas Passive Houses

Conclusions

In this study, the concept of passive house was established and the major energy technical components applied to passive house was grasped through the exploration of the overseas cases. Each case was found to follow the passive technology that minimizes energy loss and load with high-performance insulation, high-efficiency window, and air-tightness performance basically reinforced, which incorporates active components of new and renewable energy suitable for regional climate in most economic and efficient manner.

Unlike the general building process, the process of energy saving-concept building aimed at the building's energy reduction includes the analysis of a variety of design variables as well as energy performance of each component technology from the early stage of design. That is, it is characterized with that arrangement for ultra energy saving design, essential design guideline of building design such as space plan, elevation, etc.,. and quantitative analysis to absolutely meet the energy performance are intensively reviewed from the planning stage. In view of the domestic situation that 'mandatory requirement for public office to maintain 1st class energy efficiency' and 'total annual energy use' are being introduced, it is necessary to verify how energy is reduced in a quantitative manner from the planning stage different from the existing design method, and the architects need to actively participate in such change the requirement.

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