[논문] 한국태양에너지학회 논문집
Journal of the Korean Solar Energy Society

Vol. 36, No. 3, 2016
ISSN 1598-6411
http://dx.doi.org/10.7836/kses.2016.36.3.017

A Study on the POE-based Energy Utilization Satisfaction Analysis for Passive House in Germany

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(Received 18 January 2016; accepted 09 June 2016)

Abstract : Passive House represents energy-saving technologies. It aims to save energy and provide comfort to the dwellers. The design and construction began in Germany, where it is commonly observed. In South Korea, implementation of the Passive House concept is difficult because of high construction costs and technological problems. This study performed a POE analysis to analyze the extents of satisfaction and knowledge about Passive House among those who live in them in Germany. The results found high satisfaction with functional aspects, such as ventilation, windows, doors, and the thermal bridge. These research results will provide application criteria for Passive House construction in South Korea.

Key Words : Passive House, Energy-saving technologies, POE analysis

1. Introduction

Housing construction techniques have been evolving. Among the advanced techniques, energy-saving technology is the core technology. This study aims to analyze Passive House, built not only to conserve energy, but also to ensure a hospitable living environment. Passive House construction began in Germany, where many Passive Houses can be observed. On the other hand, Passive House is unusual in South Korea because of the expensive construction costs and technological challenges. Regarding these issues, this study conducted a survey (Post Occupancy Evaluation (POE)) among German Passive House residents regarding their satisfaction and knowledge. The results are expected to suggest guidelines for pursuing Passive House in South Korea.

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Table. 1 Overview of survey design

Design aspect	Contents
Survey period	November 15 - December 31, 2014
Sample	Passive House residents in München District, Germany
Method	In-person interview
Objective	Investigate the satisfaction and knowledge of Passive House residents
Passive House Size	- Below 100m^2: 47 households - Above 100m^2: 42 households
Resident status	- 1~3: 50 households - Above 4: 39 households
Passive House Location (München)	- Trudering and Waldtrudering area - Schwedensteinstr, Gerstäckerstr and Tsingtauerstr area

2. Survey Design

The objective of this study was to provide data for an empirical analysis through POE analysis. The sample comprised Passive House residents in München, Germany. Germany was chosen because it holds the fundamental technologies of Passive House . In addition, Germany implements the Passive House standard guidelines. The questionnaire had 11 questions regarding the extents of satisfaction and recognition levels of Passive House residents. Four additional questions concerned the extent to which the respondents recognized the major functions of Passive House, particularly the energy-saving functions. Table 1 provides a summary of the survey design.

3. Survey Method

There were 89 Passive House residents in München, Germany, who participated in the in-person survey, which was carried out after the respondents received detailed explanations during residential visits. The data were analyzed using SPSS[1] for exploratory factor analysis of the measurement tools, reliability analysis, and correlation analysis. The factors were extracted using principal component analysis with Varimax rotation based on the assumption of mutual independence among the extracted factors.

1) The SPSS is a software package for statistical analysis. This study utilized SPSS version 20.

4. Results

4.1 Exploratory factor analysis of the questionnaire content

Ten questionnaire items were employed based on the principles[2] of the German Passive House institute. The exploratory factor analysis found three factors: “Outside Block,” “Indoor Environment,” and “Indoor Sensible Temperature.” Among the total six questions on Outside Block (blocks air and light coming from the outside), one question was dropped. There were three items in the Indoor Environment index, and there were two items in the Indoor Sensible Temperature index.

4.2 Reliability Analysis

Reliability analysis was performed to assess the internal consistency of the measurement items. Cronbach’s α exceeded .60; which supported the credibility of the indexes (Van and Ferry)[3] (Table 2).

4.3 Correlation of variables

The correlation results are shown in Table 3 regarding the independent variables (knowledge) and the dependent variables (satisfaction).

Table. 2 Exploratory factor analysis, reliability analysis

Division	Outside Block	Indoor environment	Temperature of indoor
Airtightness of window	0.829	0.089	0.124
Thermal bridge	0.777	-0.094	-0.028
Insulation of window	0.665	0.212	0.331
Envelope airtightness	0.595	0.075	0.262
Insulation of envelope	0.591	0.382	-0.032
Comfort of indoor air	0.122	0.736	0.164
Insolation	0.372	0.691	0.043
Artificial lighting	-0.101	0.641	0.054
Temperature of summer	0.008	0.053	0.930
temperature of winter	0.409	0.218	0.718
cronbach's α	0.775	0.632	0.700

Table. 3 Correlation analysis results

Division	variables	1	2	3	4	5	6	7
independent variables	function	1						
	energy saving	.540	1					
	environment-friendly	.236	.614	1				
	financial support	.184	.273	.403	1			
dependent variables	outside block	.248	.243	.011	.203	1		
	environment	.275	.265	.153	.117	.370	1	
	temperature of indoor	.099	.291	.321	.216	.399	.295	1

2) The basic principles of German Passive House are (1) thermal insulation, (2) Passive House windows, (3) ventilation heat recovery, (4) airtight structure, and (5) absence of thermal bridges.

3) Van de Ven, A. H and Ferry, D. L., (1980): Measuring and Assessing Organizations (Wiley, New York)

4.4 Differences by general characteristics

Regarding the extents of the respondents' satisfaction and knowledge, differences were analyzed with respect to their general characteristics. Independent samples t-tests and analysis of variance were used to compare differences in means.

4.4.1 Size of dwelling

There was a statistically significant difference in satisfaction depending on the size of the house, where satisfaction was higher among the respondents whose houses were larger than 100 m^2 compared to the other respondents (Table 4).

Table. 4 T-test by number of residents

Division	group	mean	std. deviation	t-value	p-value
function of Passive House	< 100m2	3.47	.94	-0.014	0.989
	≥100m2	3.46	1.16		
energy saving	< 100m2	3.98	.84	0.119	0.906
	≥ 100m2	4.00	.89		
environment-friendly	< 100m2	3.87	.87	0.061	0.952
	≥ 100m2	3.88	.87		
financial support	< 100m2	3.27	1.14	0.118	0.906
	≥ 100m2	3.29	.87		
outside block	< 100m2	4.17	.56	2.592	0.011
	≥ 100m2	4.46	.47		
environment of indoor	< 100m2	4.09	.66	0.854	0.395
	≥ 100m2	4.20	.57		
temperature of indoor	< 100m2	3.99	.76	1.765	0.081
	≥ 100m2	4.26	.63		

4.4.2 Annual income

Satisfaction was higher (4.66) among the respondents whose annual incomes exceeded EUR 75,000 than among those with lower incomes (Table 5).

Table. 5 T-test by income

Division	group	mean	std. deviation	t-value	p-value
Function of Passive House	< 50,000	3.55	0.95	1.915	0.154
	50,000-75,000	3.24	0.99		
	≥ 75,000	3.77	1.19		
	total	3.48	1.04		
energy saving	< 50,000	3.97	0.73	1.536	0.221
	50,000-75,000	3.88	0.88		
	≥ 75,000	4.27	0.88		
	total	4.01	0.84		
environment-friendly	< 50,000	3.76	0.87	0.971	0.383
	50,000-75,000	3.88	0.88		
	≥ 75,000	4.09	0.75		
	total	3.89	0.85		
financial support	< 50,000	3.31	1.17	0.818	0.445
	50,000-75,000	3.15	0.99		
	≥ 75,000	3.50	0.80		
	total	3.29	1.01		
outside block	< 50,000	4.16	0.58	7.799	0.001
	50,000-75,000	4.19	0.49		
	≥ 75,000	4.66	0.36		
	total	4.30	0.54		
environment of indoor	< 50,000	4.11	0.71	2.965	0.057
	50,000-75,000	4.01	0.61		
	≥ 75,000	4.41	0.44		
	total	4.15	0.62		
temperature of indoor	< 50,000	4.05	0.63	6.432	0.003
	50,000-75,000	3.90	0.79		
	≥ 75,000	4.55	0.51		
	total	4.12	0.71		

4.5 Satisfaction with the Passive House by function

Between one and seven respondents were dissatisfied or very dissatisfied with their houses regarding their abilities to block noise or sunlight. However, more than 80% of the respondents were satisfied or very satisfied with the functions of their passive houses (Table 6).

Table. 6 Satisfaction with passive houses from very dissatisfied (VD) to very satisfied (VS), numbers of cases with percentages in parentheses

Division	VD	D	N	S	VS
Insulation of envelope	-	1 (1.2)	11 (12.9)	30 (35.3)	43 (50.6)
Airtightness of envelope	-	1 (1.2)	4 (4.7)	35 (41.2)	45 (52.9)
Blocking noise	1 (1.2)	6 (7.1)	25 (29.4)	31 (36.5)	22 (25.9)
Insolation	1 (1.2)	4 (4.7)	11 (12.9)	20 (23.5)	49 (57.6)
Artificial lighting	-	1 (1.2)	30 (35.3)	22 (25.9)	32 (37.6)
Comfort of indoor air	-	2 (2.4)	13 (15.3)	42 (49.4)	28 (32.9)
Temperature of summer	-	4 (4.7)	19 (22.4)	35 (41.2)	27 (31.8)
Temperature of winter	-	1 (1.2)	14 (16.5)	34 (40)	36 (42.4)
Insulation of window	-	3 (3.5)	19 (22.4)	34 (40)	29 (34.1)
Airtightness of window	-	1 (1.2)	9 (10.6)	34 (40)	41 (48.2)
Thermal bridge	-	-	11 (12.9)	37 (43.5)	37 (43.5)

4.6 Awareness analysis for the Passive House

The results of the analyses of the respondents' knowledge about Passive House showed that approximately 50% of the sample was familiar with the functions of passive house, and approximately 75% of the respondents agreed with the energy savings aspect of passive house. In addition, about 66% agreed that Passive House are environmentally friendly. As explained above, German Passive House has been implemented according to the basic principles of passive house.

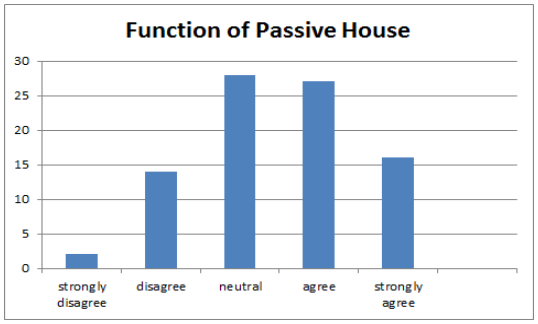

Fig. 1 Residents awareness for function

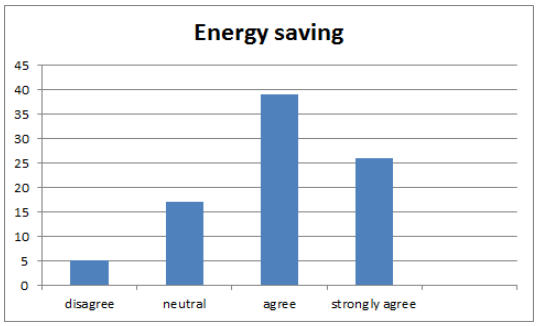

Fig. 2 Residents awareness for energy saving

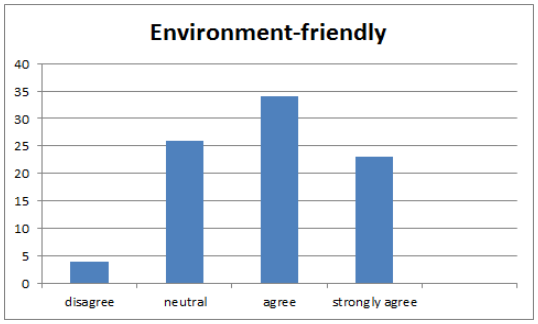

Fig. 3 Residents awareness for environment-friendly

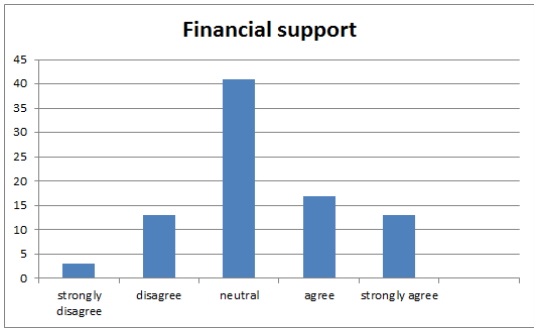

Fig. 4 Residents awareness for financial support

5. Conclusion

Passive housing has value for conserving energy and securing a pleasant living environment. Germany has the original technology. In South Korea, despite its value to efficiency, passive houses are uncommon because of their expensive construction costs and so on. This study performed a POE to analyze satisfaction among Passive House residents. The respondents were satisfied with the functional aspects of their passive houses. For example, they were satisfied with the ventilation, windows, doors, and thermal bridge. They also were highly satisfied with the houses' abilities to block noise and sunlight/artificial light, provide sensible temperatures in summer and winter, and so on. The respondents' knowledge was high as well, considering that about 50% to 70% had knowledge of the energy-saving functions, eco-friendly values, and other aspects of passive houses. In conclusion, German passive houses are efficient from the residents' perspectives.

Acknowledgement

This work was supported by a Research Grant of Pukyong National University (2015).

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Appendix. POE Survey questionnaires

Questionnaires on residential experience in Passive House

Dear Sirs,,

I would like to ask you some questions to investigate the level of resident satisfaction. The information which you would provide, would be used only for academic research. Thank you very much for your cooperation.

Prof. Hae Jo Chung
Pukyong National University,
Busan, South Korea

Question

1.1 Size of your house? _____ ㎡

1.2 Number of resident _____

1.3 Price of your house? _____ EUR

1.4 annual income

☐ <25.000 ☐ 25.-50.000 ☐ 50.-75.000,

☐ ≥75.000 EUR

Please tick off items in the following list.

	VD	D	N	S	VS
2.1 Insulation of envelope					
2.2 Airtightness of envelope					
2.3 Blocking noise					
2.4 Insolation					
2.5 Artificial lighting					
2.6 Comfort of indoor air					
2.7 Temperature of summer					
2.8 Temperature of winter					
2.9 Insulation of window					
2.10 Airtightness of window					
2.11 Thermal bridge					

VD = very dissatisfied
D = somewhat dissatisfied
N = neutral
S = somewhat satisfied
VS = very satisfied

	SD	D	N	A	SA
3.1 I know the function of Passive House.					
3.2 I think that they can save energy in Passive House.					
3.3 I think that Passive House is Environment-friendly.					
3.4 I think that the financial support for Passive House is enough.					

SD = strongly disagree
D = disagree
N = neutral
A = agree
SA = strongly agree