ANALYSIS OF ENVIRONMENT-FRIENDLY BUILDING MATERIALS FOR AGED HOUSING REMODELING

Ki-Hyon Kim[1] **and Kyung-Rai Kim**[2] **and Hee-Sung Cha**[3]
[1] Ajou University, San 5, Woncheon-Dong, Yeongtong-gu, Suwon, Korea
[2] Ajou University, San 5, Woncheon-Dong, Yeongtong-gu, Suwon, Korea
[3] Ajou University, San 5, Woncheon-Dong, Yeongtong-gu, Suwon, Korea

Abstract

"Environmentally Sound and Sustainable Development (ESSD)" is a key word in recent years. The construction industry, have put a great influence on ergonomic and sustainable environment. Recently, "green building certifications", such as Indoor Air Quality (IAQ) and eco-friendly material regulation have been established. With this regard, new construction and aged-housing remodeling projects are required to meet these certification criteria. Multi-housing residents have great concern on eco-product, since many cases are reported that Sick Building Syndrome is caused by toxic substance from building materials. Aged-housing remodeling project is very unique in that building residents are selected prior to design phase. Therefore, the analysis of resident's need for building materials in aged-housing remodeling is relatively easy compared to new building construction. As such, it is very important to analyze their preferences for eco-friendly materials prior to project execution. The purpose of this study is to find the needs of residents and priority of their needs. Based on their needs and priority, this paper provides a new strategy in using environment-friendly materials and maximizing their satisfaction level when aged housing remodeling is constructed. In addition, this paper provide new criteria in selecting new developed environmental materials in remodeling projects for the purpose of improving the safety and health level in construction industry.

Keywords: Eco-friendly, Aged housing remodeling, resident needs analysis, material selection

1. Introduction

1.1 Research background

"Eco-friendly construction" is an emerging issue in building industry. The main purpose of eco-friendly construction is to sustain the health and environment of building residents and to minimize the harmful effect on their environment.[2] Moreover, the eco-friendly construction has become a necessity in maximizing the benefits of the construction companies and has become one of the main project objectives. Building construction produces noises and raises dusts during construction and produces various construction wastes and it worsens the environment.[3,4] Resident's health and comfort are influenced by various factors including indoor environment, temperature, humidity, illumination and noise, etc. Poor indoor environment quality can make the occupants feel discomfort and sick, when pollutants are emitted from interior finishing materials or furniture and other facilities. Recently, standardization and regulations on Indoor Air Quality have been established and have become major concerns. As such, it is strongly recommended that new construction and aged housing remodeling should consider these environment-issues.

Multi-housing residents have high concerns on eco-product or materials in many cases it is widely reported that Sick Building Syndrome(SBS), is caused by toxic substance from building materials.[5] Especially, aged-housing remodeling construction has a unique characteristic in that the residents are already determined prior to construction execution. So, analyzing residents' cognition in terms of the preferred performance in aged housing remodeling is an important issue. So, it is quite crucial to recognize their needs. However, construction companies are reluctant in considering resident's preference in an active way. Instead they apply eco-products which are certified as the best materials from Korean Eco-Products Institute (KEPI) for their company marketing without residents' consideration of needs. Also, residents are lack of understanding the certification standards of eco-product. In short, they only rely on the grade of eco-product, and it is not easy to select performance-based materials. These problems in aged housing remodeling can be solved by application of new eco-product in a more systematic way with consideration of economic value of the target building materials.

1.2 Research methodology

It is essential to analyze eco-product certification standards in remodeling projects for reliability assurance one of the simplest way to do this is to recognize resident's satisfaction level. By project managers can easily examine the performance criteria of environment-friendly materials that the residents prefer, and analyze the results in a quantitative way. Then, the priority order of the residents' preferences can be derived for the purpose of suggesting possible alternatives with lower cost and high performance. The objective of this study is to derive environmental characteristics and their performances of building materials and provide the outputs of the resident survey using the organized by investigating resident preference.

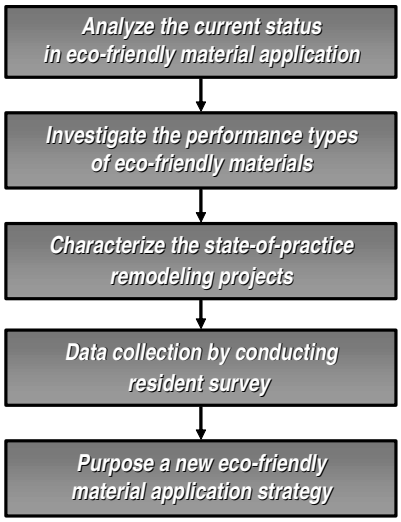

Figure 1: Depicting the detailed research process in this study

2. Current status of using eco-friendly materials in remodeling construction

To identify environment-friendly performance of building materials, the authors analyzed various resources, including LEED[1][1], GBTool[2], Certification of Environment-Friendly Building Design[3],

[1] LEED (Leadership in Energy and Environmental Design) : National standard for developing high-performance, sustainable buildings construction in USGBC (U.S. Green Building Council).

performance of Symbiotic Housing[4] , Green Building Rating System[5]. Based on the literature review, the authors compiled the various types of eco-friendly performance for a particular building material.[1,5] It is noteworthy that the performance types are limited to finishing material. The complete list of eco-friendly performance type is provided as shown in table 1.

Table 1: Environmental Performance types of building materials

Building materials	Eco-friendly performance type
Flooring	Contaminant reduction, Recycling, Far infrared ray emission, Floor draft isolation, Floor impact noise reduction, Natural material use
Paint	Low-VOC[6], Non-toxious ingradient, Contaminant removal, Healthful material emission
Wallpaper	Low-VOC, Recycling, Humidity control, Air purification, Natural material
Insulator & Sound absorbing material	Recycling, Insulation & Sound absorption, Durability, Non-inflammability, Contaminant reduction, Recycling
Wall/Ceiling finish	Low-VOC, Recycling, Waterproof, Germproof, Fireproof, Insulation & Sound absorption
Floor impact noise reducer	Recycling, Floor impact noise reduction, absorptiveness reduction
Window	Contaminant reduction, Energy Saving, soundproof, Ventilation performance
Adhesive	Low-VOC, Non-toxious ingredient, Humidity control, hazardous article removal
Tile	Recycling, Non-toxious ingredient, Mold reduction, Durability

3. Applying eco-materials in remodeling projects

3.1 Questionnaire result analysis

The six building materials (i.e., included in table 1) are selected based on Korea Eco-product Institute. Once the performance types have been identified, the authors performed on-site building survey in order to recognize the importance level from the perspective of the residents.

The survey was conducted by requesting the residents to score the importance level of each performance on the corresponding building materials. For each building material, the selected performance types were summated to 100 score. The resident survey was conducted from April 19 2006 to April 26 2006. The survey respondents were selected by considering the dwelling period. The number of survey respondents amounted to 74. To efficiently identify the important performance types for each building material, the authors used the following selection process in choosing the most important performance type(s).

Step 1: Exclude performance type(s) with less than 50% residents' choice rate
Step 2: Exclude remarkably low scored performance type(s)
Step 3: Determine the cluster level based on dendrogram analysis

[2] Environmental performance assessment method which developed as part of the GBC(Green Building Challenge) process, an international effort to establish a common language for describing Green Buildings, which includes teams from 20 countries.
[3] Estimation model was developed to solve problem such as earth environmental problem, immoderate city increase, nature ecosystem breakdown, human alienation phenomenon in Architectural Institute of Korea.
[4] Estimation techniques developed to choose Symbiotic Housing in Japan Construction Ministry.
[5] Evaluation standard was developed that based on GBTool for South Korea at Green Building Council KOREA(GBC-KOREA).
[6] Volatile organic compounds: liquid or gas organic compound that is evaporated easily in the air. It is toxic chemical substance that negative impact surrounding and human health.

Cluster analysis is a method for grouping similar elements into a cluster. In other words, cluster analysis is an exploratory data analysis tool which aims at sorting different elements into groups using the degree of association among the elements. Cluster analysis was performed by the SPSS 12.0 which is a software package for statistical analysis. Since performance levels for each finish material are difficult to quantify, cluster analysis is a useful when recognizing the residents' needs in terms of eco-friendliness of building materials. (see figure 2)

Cluster Membership

Performance Type	Cluster No.
Contaminant	1
Recycling	2
Far infrared ray	2
Floor Draft	2
Reduce floor impact &noise	1
Using natural materials	1

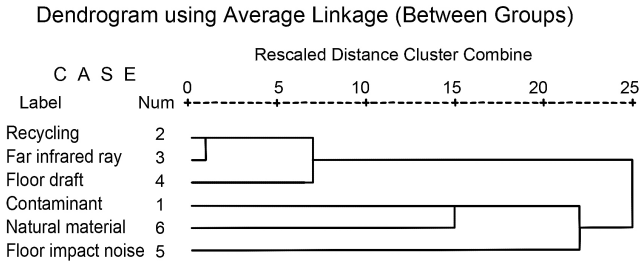

Figure 2: cluster analysis example: flooring

As can be seen from Cluster Membership table in figure 2, contaminant reduction, floor impact noise reduction and natural material use are grouped into cluster 1 (group of high average score), and recycling, far infrared ray emission and floor draft isolation are grouped into cluster 2 (group of low average score). In addition, as can be seen from the dendrogram, which measures the distance in terms of similarity, similar elements are located in a near place. Cluster 1 includes contaminant reduction, floor impact noise reduction and natural material use. Cluster 2 includes recycling, far infrared ray emission and floor draft isolation. Throughout this process, the group which acquires higher grades can be easily selected by reflecting the resident's needs. Also, the priority order can be obtained by analysing the average of each performance type.

3.1.1 Flooring

As provided in table 2, floor impact noise reduction has the highest score of 28.47 in flooring. "Natural material use" and "contaminant reduction" are selected as performance criteria in considering eco-friendly remodeling project. The other performance types such as recycling, far infrared ray emission, floor draft isolation are excluded in the performance criteria. It is noteworthy that far infrared ray emission is not included because of low choice late (47.30%). Therefore, when selecting the best eco-friendly material in flooring, it is recommended that the above performance types should be regarded as crucial performance in remodeling projects.

3.1.2 Wallpaper, paint, adhesive, wall/ceiling finish

For paint, wallpaper and adhesive, "low-VOCs" is the top priority in eco-friendly performance. Other performance types are excluded in the performance criteria for these building materials. "Insulation & sound absorbing" performance is also regarded as significant performance base on dendrogram analysis

3.1.3 Insulation and sound absorbing materials

Durability, non-flammability and contaminant reduction are classified into important performance criteria. In particular, "containment reduction" is chosen as the most important factor in eco-friendly buildings.

3.1.4 Window

For window material, there are three performance types included in the eco-friendly performance. "Contaminant reduction (28.14)" ranks highest as shown in table 2. "Energy saving (26.05)", "soundproof (27.67)" should also be considered as eco-friendly performance based on the residents' survey.

3.1.5 Tile

"Mold reduction (30.61)" performance is the major criterion in consideration of eco-friendly material for tile material. Non-toxious ingredients (29.32) and durability (25.27) are considered as important factors for tile material selection in the survey.

Table 2: Result of residents' survey

Item	Performance	Averaged important level (Max: 100)	Standard deviation	Selection rate		Cluster No.	Priority order	Significant performance
				Frequency	Choice rate			
Flooring	**Contaminant reduction**	23.76	15	N/A	N/A	**1**	**3**	**Yes**
	Recycling	7.41	9	N/A	N/A	**2**	**6**	**No**
	Far infrared ray emission	17.11	9	35	47.30%	**2**	**4**	**No**
	Floor draft isolation	16.93	10	40	54.05%	**2**	**5**	**No**
	Floor impact noise reduction	28.47	14	72	97.30%	**1**	**1**	**Yes**
	Natural material use	24.22	12	73	98.65%	**1**	**2**	**Yes**
Paint	**Low-VOCs**	40.10	15	N/A	N/A	**1**	**1**	**Yes**
	Non-toxious ingredient	29.36	11	N/A	N/A	**2**	**2**	**No**
	Contaminant removal	15.30	9	74	100%	**2**	**3**	**No**
	Healthful material emission	15.24	11	74	100%	**2**	**4**	**No**
Wallpaper	**Low-VOC**	38.48	14	N/A	N/A	**1**	**1**	**Yes**
	Recycling	11.11	9	N/A	N/A	**2**	**5**	**No**
	Humidity control	15.01	8	74	100%	**2**	**4**	**No**
	Air purification	18.48	9	74	100%	**2**	**2**	**No**
	Natural material use	16.93	12	74	100%	**2**	**3**	**No**
Insulator & Sound absorbing material	Recycling	9.70	7	N/A	N/A	**2**	**6**	**No**
	Insulation & Sound absorption	17.26	10	N/A	N/A	**2**	**4**	**No**
	Durability	22.35	13	61	82.43%	**1**	**3**	**Yes**
	Non-inflammability	23.74	12	64	86.49%	**1**	**2**	**Yes**
	Contaminant reduction	29.89	13	71	95.95%	**1**	**1**	**Yes**
	Recycling	16.67	9	24	32.43%	**2**	**5**	**No**
Wall/Ceiling finish	**Low-VOC**	28.86	14	N/A	N/A	**1**	**1**	**Yes**
	Recycling	7.85	7	N/A	N/A	**2**	**6**	**No**
	Waterproof	18.69	9	42	56.76%	**2**	**5**	**No**
	Germproof	20.33	8	63	85.14%	**2**	**4**	**No**
	Fireproof	21.51	7	57	77.03%	**2**	**3**	**No**
	Insulation & Sound absorption	24.40	13	57	77.03%	**1**	**2**	**Yes**
Window	**Contaminant reduction**	28.14	14	74	100%	**1**	**1**	**Yes**
	Energy Saving	26.05	13	74	100%	**1**	**3**	**Yes**
	soundproof	27.67	10	74	100%	**1**	**2**	**Yes**
	Ventilation performance	18.14	9	74	100%	**2**	**4**	**No**
Adhesive	**Low-VOC**	37.77	14	N/A	N/A	**1**	**1**	**Yes**
	Non-toxious ingredient	27.36	9	N/A	N/A	**2**	**2**	**No**
	Humidity control	13.31	9	74	100%	**2**	**4**	**No**
	hazardous article removal	21.55	9	74	100%	**2**	**3**	**No**
Tile	Recycling	14.80	9	N/A	N/A	**2**	**4**	**No**
	Non-toxious ingredients	29.32	13	N/A	N/A	**1**	**2**	**Yes**
	Mold reduction	30.61	11	74	100%	**1**	**1**	**Yes**
	Durability	25.27	10	74	100%	**1**	**3**	**Yes**

* Default is a conventional performance type. Respondents don't need to select this performance type because that is an currently applying criteria without residents' consideration

3.2 Modified eco-friendly materials on remodeling project

Table 3 provides two listings of building materials; one is based on conventional selection method and the other is based on resident needs analysis. It is interesting that there is a big difference between two results. For example, in conventional-based selection, wood flooring in living room where as "natural material ryum carpet" and "floor covered with buffer layer" is the best in resident-based selection. Not only for this, in most building elements, conventional-based materials are totally different from resident based selection. This result indicates that eco-friendly materials should be selected in consideration of residents' needs or preferences.

Table 3. Comparison of Environmental materials

Category		Conventional-based environment-friendly materials	Resident's need-based environment-friendly materials
Living room	Flooring	Wood flooring	Natural material Ryum carpet, Floor covered with buffer layer
	Wall	Laminated wallpaper, High-quality silk wallpaper, Natural wallpaper	Natural wallpaper, Leachy wallpaper that adsorb VOCs
	Ceiling	High-quality silk ceiling paper	Natural ceiling paper
Kitchen	Flooring	Wood flooring	Natural material Ryum carpet, Floor covered with buffer layer
	Wall	Laminated wallpaper, High-quality silk wallpaper, Natural wallpaper, Wallpaper tile	Korea traditional wallpaper, Leachy wallpaper that adsorb VOCs
	Ceiling	High-quality silk ceiling paper	Natural wallpaper
Bed-room	Flooring	Vinyl laminated paper lacquered with bean oil	Natural material Ryum carpet, Floor covered with buffer layer
	Wall	Laminated wallpaper, High-quality silk wallpaper, Natural wallpaper	Natural wallpaper, Leachy wallpaper that adsorb VOCs
	Ceiling	High-quality silk ceiling paper	Natural ceiling paper
Bath-room	Flooring	Porcelain tile	Antifungal tile
	Wall	Ceramic tile, Natural marble	Antifungal tile
	Ceiling	louver	N/A
Balcony	Flooring	Porcelain tile	Antifungal tile
	Wall / Ceiling	Exterior water paint, Anti mould paint, Anti condensation paint, eco-paint	Natural paint, VOCs reduction paint
	Window	Aluminum window	System windows with natural ventilation performance

4. Conclusion

This study, addresses environment-friendly materials that are selected based on residents' needs. Recently, eco-friendly materials and methods are no more optional in construction industry. In remodeling project, the building residents are crucial when selecting and/or deciding the most appropriate materials. The negligence of the residents' can cause the inefficiency when developing eco-friendly building environment. To solve this problem, this study provides resident's need-based building materials. When compared to the traditional selection method, these materials have been identified as the potential building material listing. When the findings of this study are considered in earlier stage of remodeling building projects, the eco-friendliness of the project can be improved and the satisfaction level of building residents can be higher. Ultimately, the performance of environmental sustainability can be achieved in an effective way.

Acknowledgment

This research is part of a research project (Grant No. 05-CTRM-D06: Construction Core-Technology Research & Development) sponsored KICTTEP(Korea Institute of Construction & Transportation Technology Evaluation and Planning). The financial support is gratefully acknowledged.

References

[1] **Leadership in Energy and Environmental Design(LEED) (2002),** "Green building rating system™ version 2.1"

[2] **Michael A. Lacasse(1999),** "Materials and technology for sustainable construction", Building Research and Information, International council for building research, 27(6), 405-408.

[3] **Nick Raynsford(1999),** "The UK's approach to sustainable development in construction", Building Research and Information, International council for building research, 27(6), 419-423.

[4] **Richard C. Hill, et al.(1997),** "Sustainable construction: principles and a framework for attainment", Construction Management and Economics, 15, 223-239.

[5] **Ryu, J. Y.(2003),** "A study on the planning of environmentally friendly remodeling", Master Thesis, Seoul National University (SNU).