AN INTEGRATIVE ASSESSMENT SYSTEM FOR BUILDING AESTHETICS APPLIED WITH PHOTOVOLTAIC CELLS

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Abstract - The purpose of this research is to construct an aesthetic evaluation system for buildings with solar cells applied. The current solar cell is applied to buildings mainly for energy performance, and this is the situation where the method of aesthetic expression of the building has not been established. Therefore, in this research, the application plan was analyzed for solar cells considering the characteristics of solar cells and the characteristics of building façade. The analysis method derives aesthetic elements through preceding research and cases of BIPV buildings and derives objective and consistent evaluation elements through three processes. Based on these evaluation systems, as a future research, this paper will suggest to construct quantitative and objective data through AHP (Analytic Hierarchy Process) and VE (Value Engineering) analysis and try to construct aesthetic design guidelines for BIPV (Building Integrated Photovoltaics) buildings.

Index Terms - Aesthetics, Building Façade, BIPV (Building Integrated Photovoltaics), Solar Cells

I. INTRODUCTION

The problem of global warming becomes serious, problems of fossil fuel exhaustion and environmental pollution are displayed on a continuous topic, and various research and policies for new regeneration of energy are being promoted worldwide. However, current solar cells are under active research on architectural integumentary systems in terms of energy performance of buildings, and in terms of design, they are in short supply. Against these backgrounds, this study analyzes the esthetic elements of BIPV buildings and builds an esthetic evaluation system based on the analyzed elements. The constructed evaluation system will go through quantitative evaluation and ultimately provide aesthetic evaluation guidelines for BIPV (Building Integrated Photovoltaics) buildings.

II. THEORETICAL SPECULATION

A. Definition of Renewable Energy and Solar Cells

New regeneration energy can replace fossil fuels and the importance of sustainable energy is being re-recognized. It is a resource that pursues green growth and excels in the possibility of the future with energy using nature such as sun, water and wind. As an advantage of the solar cell, there is an advantage that the energy source is an infinite resource, it is installed in a necessary place and energy can be acquired for long life and unattended. In addition, the present solar cell can be applied to building façade, it functions as an exterior material of a building at the same time as energy production, and it is superior in utilization for the design of the façade of a building. The configuration of the solar cell is composed of cells, modules, and systems.

B. Types of Solar Cells

Current solar cells can be divided into first generation crystalline silicon solar cells, second generation thin film solar cells, the third generation dye sensitive solar cells.

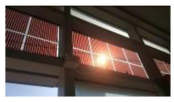
First generation PV	Second generation BIPV	Third generation DSC
		
Balcony	Wall	Windows
		
Roof	Roof	Windows
		
Other	Shading Device	Other
PV is installed on another site or roof and it is not transparent.	BIPV is transparent and can be applied to various parts of the building.	DSC is capable of expressing various colors and is environmentally friendly.

Table 1. Types of Solar Cells

B. BIPV Consideration Factors

In order to increase the efficiency of the solar cell, the slope and the azimuth, shade and temperature are the most fundamental factors to consider. In order to consider these parts, it is necessary to have a system that understands the characteristics of the photovoltaic power generation module, simulates the energy performance according to the situation of the building, and sets the place to be applied beforehand.

Solar cells are devices that produce electricity using the sun's light, and the efficiency part should be considered preferentially. Therefore, the aesthetic evaluation system will analyze the performance of the BIPV as well as the preceding research, and try to construct an evaluation index of aesthetics considering the characteristics of the solar cell material itself.

III. AESTHETIC ELEMENT ANALYSIS

A. Properties by the Type of Building Installation

Solar cells are mainly applicable to places where the sun's light is illuminated and can be applied in various ways to the parts of the façade of the building. The solar cell applied to the façade can be categorized into a vertical plane, upper plane, etc. according to the application position, and the aesthetic characteristics formed based on the application position are as follows.

Applying position	Application method		
Vertical (outer wall)	Attachment Type	Integral Type	Window Type
Upper (roof)	Sloped Roof Type	Flat Roof Type	Other Roof Type
Etc. (Shading Device)	Vertical Shading Device	Horizontal Shading Device	Balcony

Table 2. Application Types for Solar Cells

B. Characteristic Analysis on Aesthetics of Building Façades

Preceding research of building façade views were divided into two types and analyzed. The type was divided into a landscape view point and an architectural view point and the elements of the esthetics selected the primary elements via the mentioned frequency of the elements using the analysis of preceding research. The scope of the research was analyzed with an emphasis on the aesthetics of the form of the building, and factors such as convenience and place-ability analyzed from the viewpoint of the landscape were excluded. First of all, the architectural point of view means the artistic beauty that the building itself possesses, and the point of the landscape means the ambient beauty created in harmony with the surroundings.

Main Category	Middle Category	Definition
Architectural Characteristics	Proportion	Means the ratio of vertical and horizontal elements of target
	Shape	Means the external form of the object
	Structure	Meaning aesthetic elements that can be displayed in structure
	Color	It means the ratio of the target main color, auxiliary color, highlight color, etc.
	Design	In addition to the structure, decorative elements for aesthetic expression
	Material, Texture	Visual harmony and satisfaction of the material displayed on the façade
	Scale	It means the extent of the size with the surrounding buildings.
Landscape Characteristics	Natural Environment Conformity	Means how buildings are harmonized with the natural environment
	Color Conformity	Whether the building harmonizes with the color of surrounding buildings and cities

Table 3. Criteria for Aesthetic Elements for Building Façade

As a result of analyzing preceding research of architectural viewpoints, there were many studies involving urban content, but in this research, emphasis was placed on deriving only the most basic elements of buildings. The element derivation process of the landscape view point is the same as the architectural view point, and additional, the suitability of the evaluation factor of the esthetics was analyzed. Of the elements analyzed through advanced research, the elements of the evaluation range overlapping with similar meanings were join or excluded.

Main Category	Middle Category	Small Category
Architectural Characteristics	Proportion	Building Proportion
		Opening Proportion
	Shape	Originality

		Symbolism
		Facility
	Structure	Regularity
		Shape Representation
	Color	Ratio
	Design	Molding
		Recognition
	Material, Texture	Expressivity
		Harmony
	Scale	-
Landscape Characteristics	Natural Environment Conformity	Landscaping
		Environment Friendliness
	Color Conformity	Surrounding Landscape Conformity
		Conformity of Urban Landscape

Table 4. Indexes for Aesthetic Element of Building Façade

C. Analysis of Solar Cell Aesthetics

Analysis focused on advanced research, the type was divided into two. It was divided into characteristics of material and characteristics of installation type and analyzed. The characteristics of the material are analyzed based on the advanced research, and the characteristics of the type of installation were derived using advanced research and on-site investigation.

Main Category	Middle Category	Definition
Solar cell	Color	Color harmony and uniform color expression of solar cells
	Shape	Harmony between the form of the solar cell and the building
	Integral	Whether the solar cell appears to be integral with the building or not
	Transmittance	Visual view state

Table 5. Criteria for Aesthetic Elements of Solar Cells

Main Category	Middle Category	Small Category
Solar Cell	Color	Harmony
		Uniformity
	Shape	Satisfied
		Harmony
	Integral	Processing technology
		Integral
	Transmittance	Openness assessment
		Comfortable
		Mining

Table 6. Indexes for Aesthetic Element of Solar Cells

The property of a material means an aesthetic element in which a material can express. The type of analysis was analyzed separately into BIPV and DSC depending on the type of material. Analysis content was analyzed characteristics according to material, grasp elements such as expressivity and nature. The type of installation means an aesthetic element that can be expressed depending on the type of installation and analyzed the main characteristics depending on the type of installation. As a result of advancing the frequency analysis of the elements of the advanced research, the BIPV design elements were mainly analyzed for color, shape, module, harmony, and integrity with the building, the design elements of the DSC were translucency and color elements were analyzed. Translucency is an element that means view state. Although the detailed elements included physical elements, except for this, only the aesthetic elements were derived. Elements of integrated solar cells are a total of four elements: color, shape, integrity and building transparency. The element commonly analyzed in BIPV and DSC solar cells is color. The terms and explanations for the elements are described using Table 5, and the minor classification items that combined the elements of BIPV and DSC solar cells were described in Table 6.

IV. INTEGRATION OF EVALUATION ELEMENTS OF ESTHETICS

A. Integration of Evaluation Scope

Category	Range		Explanation
Façade	Minimum	Building	Buildings and structures etc.
	Maximum	Landscape	Surrounding landscape including the building (city)
Solar Cell	Minimum	Solar cell	Solar cell configuration cell, module, array
	Maximum	Building	Building and solar cell

Table 7. Evaluation Range

The part which this study must consider to be important in the process of integrating the building's façade view and the elements of the solar cell aesthetics is the integration of the evaluation range. Construction façade evaluates the surrounding landscape from the evaluation of the building. The evaluation range is larger than that of the aesthetic property of the solar cell, but it has not evaluated in detail.

B. Integration process

In order to integrate the elements, a process of reclassification with 50 elements analyzed by advanced research was conducted. Elements meaning overlapping are combined, and elements which do not correspond to BIPV are excluded. Based on the reclassified elements the terms were changed to architectural terms. 24 elements derived in such a process were classified in a secondary manner based on the range of evaluation. Integrated in a way to separate elements of building façade and solar cells. Using the concept of short distance, medium distance and long distance, this study classified it into the scope of evaluation on the material aspect, architectural side and urban side. In the tertiary classification, evaluation of the site is proceeding based on the analyzed 24 elements, and the possibility of evaluation was verified. The evaluation site was selected for 8 BIPV buildings located in Seoul, and the selected target site was selected as the representative target site of installation type. Evaluation items were revised focusing on the possibility of evaluation through field evaluation. Elements that cannot be objectively evaluated are excluded, and overlapping evaluation factors are joined. Firstly, after reclassification process three times with 50 items, finally 14 items were derived.

C. Final aesthetic element

Evaluation factors of BIPV aesthetics final derived are as follows.

Main Category	Middle Category	Small Category
Material Characteristic	Material Type	Configuration
	Installation Type	Method
		Gainliness
	Applicability	Persistence
		Conformity
Architectural Characteristics	Shape	Openness Assessment
		Symbolism
	Color	-
	Design	Design Molding
		Design Harmony
		Structure
Landscape Characteristics	Natural Environment Conformity	-
	Around Environment Conformity	-
	Color Conformity	-

Table 8. Evaluation factors of BIPV aesthetics

CONCLUSION

The contents of the research on the aesthetic evaluation system considering the characteristics of the solar cell itself are as follows. Firstly, this study found that the material characteristics of the solar cell and categorized the BIPV building based on it. In this study, the type corresponding to the application position was set as a representative type, and the aesthetic characteristics corresponding to the applied position were analyzed. A BIPV building can be categorized into a vertical surface (outer wall), an upper surface (roof) and other (shading device). Secondly, as a result of deriving elements of aesthetics separating into solar cell characteristics and architectural characteristics, 50 elements are derived primarily, three reclassification processes proceed, and finally 14 Number of elements were derived. In this research, the consecutive paper will further include to evaluate the AHP importance of the evaluation factors, analyze the priority order among the evaluation factors through AHP evaluation, and advance the construction of the evaluation system with the element weights set.

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