

ARCHITECTURAL UTILIZATION OF COLORFUL MATERIALS FOCUSED ON DYE-SENSITIZED SOLAR CELLS

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Abstract - The Purpose of this study is to suggest guidelines for color design according to architectural use, especially for dye-sensitized solar cells (DSC). Even for the same application, the efficiency of color application will vary depending on the size or application area. The designer must meet the needs of the user through the detailed composition of the size and coverage area, and the necessity of suggesting an auxiliary and a highlight color centering on the cast color through the ratio of each area. Even if it is a representative color, the color satisfaction differs depending on the material regarding on the emotional image to be obtained through color. At this point, solar cells should focus on the implementation of one image through color research. As a result of the study, the evaluation methods for color utilization were considered to be a rough and reliable test for the existing buildings. Therefore, it can be concluded that the color utilization analyses derived from the research can be meaningful in developing dye-sensitized solar cells, an advanced type of BIPV (Building Integrated Photovoltaics) having colors.

Index Terms - Colorful Materials, Photovoltaic Cells, Dye-sensitized Solar Cells, Emotion Technology

I. INTRODUCTION

Recently, it has been a long time since the solar cells applied to buildings, and in particular, BIPV (Building Integrated Photovoltaics) to be a part of architectural components. BIPV is one of the elements of the skin component such as glass and paint. BIPV has performance in both quantitative and qualitative aspect, and the effect of using BIPV is also being increased in aspects of energy generation. However, as part of the building skins of architectural design, solar cells still reveals its vulnerability, and due to the lack of aesthetic parts, especially in aspects of color harmonization on building envelopes, they cannot easily be used on the architectural design. Like this, dye-sensitized solar cells (DSC) began to use extensively on building skins and/or roofs in order to express colorfulness of the building. But, it is still a difficult material for architectural design. Therefore, DSC requires a unique color modulation method to be used practically for buildings. Exploration of the color utilization for previous and ongoing researches is the first prerequisite for the preparation of using colorful materials like DSC. With these considerations, the purpose of this study is to suggest guidelines for color design according to architectural use, especially for dye-sensitized solar cells (DSC). Furthermore, it is also included to find the measurable test for color utilization for buildings while they are expressing a variety emotions to express their design concepts and expected functions.

II. SCOPE AND METHOD OF RESEARCH

A. Characteristics of Photovoltaic Cells

It was organized into a table by combining the

aesthetic appearance characteristics with BIPV installation type classification and its characteristics extracted from the previous review thesis called “an analysis of characteristics on CIGS thin film solar cell module for BIPV applications,” by Jisung Kim. This thesis mixed both foreign and domestic examples but by changing it into only domestic, it became more suitable for the domestic BIPV market and allowed for a practical usage of BIPV domestically and a contemplation of aesthetic appearance. There were categories unsuitable for categorizing installation type after changing to a domestic example so these were changed to ones that were more suitable.

Type categorization from the extracted thesis categorized by BIPV installation location or the type of BIPV installed but looking at the domestic example, it was deemed more suitable to categorize the effects of installation location and installation range for assessment of effects it has on aesthetic appearance, hence why it was categorized like table 1. Based on the categorized examples, on-site survey locations were chosen and by visiting locations such as Songdo Global Campus, Gaet-Beol Tower and Orakai Hotel all located in Incheon, Korea, it was learned that the amount of effect each structure had on aesthetic formation or its characteristics differed depending on the location. As a result, to help with the assessment of the aesthetic formation of the structure, domestic examples were categorized into types according to installation location and an example was added to aid understanding. During the process of making assessment categories, a thought that the BIPV type and aesthetic formation characteristics could change with the usage of the structure and in order to study this deeper the structures were categorized into uses in

table 3. However, aesthetic characteristics were difficult to specify and usually appear in the forms of efficiency and performance, drawing the conclusion that it would not affect the assessment of this thesis. With a basis on the categorization of BIPV installation type based on an existing thesis, BIPV assessment categories were deducted and examples were organized for a preliminary assessment.

구분	BIPV 설치 유형			
	창호적용	파사드전체, 주 연대상 적용	일부, 인 연대상 적용	난간형
사례				
미관형성 특징	외부 마감재의 수면 통풍이 되는 cold facade에 유리 열적부하 고려한 여유공간의 확보가 필요해 일면미관에 영향			지하철입구, 건물 로비공간 등에 많이 적용됨 수직 파사드에 비해 중립스카일에서의 미관에 미치는 영향이 작음

Figure 1. Characteristics of Aesthetic Formation Classified by BIPV Installation Types

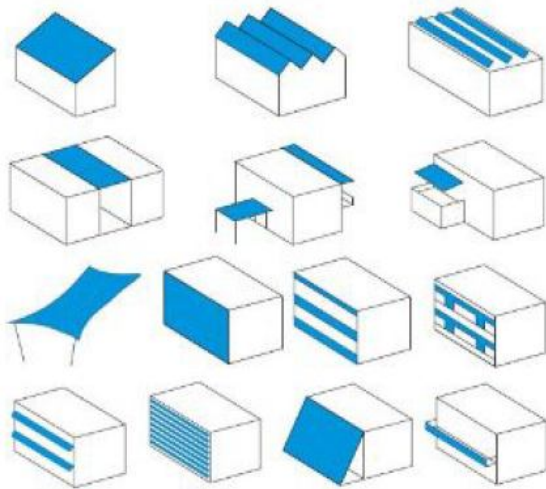


Figure 2. Alternative Locations to Install Solar Cells on a Building Structure

B. Color Utilization on Buildings

Color control began to develop in the 1920s, and it began to spread in earnest from the US military plant in the Second World War. At that time, the US military factories hired unskilled workers such as women as a result of the lack of parks, resulting in a decrease in work efficiency and frequent occurrence of safety accidents. Color control was used as a way to solve this problem. For example, yellow indicating dangerous places and white lines separating action range reduced accidents and disasters. Also, the green color that displays the machine, and the color that makes the face and handle easier to see, increased

production and reduced rejects. And harmonious colors improved work attendance and increased the motivation of labor. This technology was promoted as a private building outside the military plant by the propagation of the American paint company in the postwar period. In the early days, it began to be distributed to factories and hospitals to clearly indicate machines, and gradually spread to schools, offices, and stores. This ripple occurred at the same time in Europe.



Figure 3. Color Harmonization Tool

However, since the 1950s, criticism of color control began to arise in architecture, mainly due to the following problems. That is, it is difficult to measure the color effect, the fact that the experimental basis is not clear, the color adjustment theory is inadequate, and it shows wide effect according to the efficiency of illumination. And lack of consideration of the climate and history of the style of architecture or country. After that, the color adjustments were revised and the term "color planning" was generally used, and today's color adjustments are treated as part of the color plan.

Characteristics	Definition
Advances and Backwardness	When you see two colors at the same distance, one side looks closer or farther away than the other
Clarity	When two colors are colored, it is visible from a distance. The larger the difference in brightness and color, the higher the clarity. The degree of clarity is increased or decreased by the relationship with the background than the characteristic of the color
Temperature Sensitivity	Feelings of warmth and coolness due to color. It is mainly influenced by color, warm color is warm and white color is cold.
Accordingly Emotion	There is accompanying feeling through color. For example, a one-color system can make food tasteless. The lustrous line makes the food look more delicious.

Table 1. Characteristics of Color Utilization

Researching feature of color, color precedence investigation of color (dominance color, assistance color and highlight color) raised understanding of color. Color is the light and darkness of things that result from the absorption and reflection of light. The

closer the distance between the colors in the prism color, the more contrasting the colors are in contrast to the harmonious colors. In the color design of the elevation, it can be separated in dominance color, assistance Color, highlight color. Dominance color and assistance color are able to use color of the same group, highlight color can be use contrast color.

III. DETAILED PROCESS OF COLOR SURVEY FOR EXISTING BUILDINGS

It can be seen that there are temperature sensation and accompanied emotion among the color features, there is an associative image of color as an extension to this. When we see the color, we think of the related image. For example, when you see black, think of the night or reminiscent of the devil. Color has a psychological feeling of temperature, weight, tone, touch, etc.

Color	Concrete reminiscence	Abstract Reminiscence
Red	Blood, fire, sun, sunrise, evening glow, strawberry, tomato, apple, cherry. Roses, fire engines, red flags, war, communist parties, Christmas	Love, mature, passion, libido, obsession, anger, excitement, tension, danger
Yellow	Chick, butterfly, sunflower, forsythia, chrysanthemum, dandelion, banana, lemon, melon, month, gold, grain, light, sunny, spring	Hope, hope, lightness, liveliness, cheerful, light and soft, pleasantness, distrust, cowardice, jealousy
Blue	Sky, sea, water, lake, river, summer, jeans	Cleanliness, coolness, coolness, cold, ruthlessness, youth, hope, refreshment, eternity, sincerity
Green	Leaves, trees, forest, grass, meadow, mountain, grass, field, tea, watermelon,	Freshness, freshness, stability, comfort, rest, life, quietness, balance, relaxation, neutrality, peace, fairness

Violet	Morning glory, pansy, violet, iris, grape branch	Nobility, elegance, splendor, solitude, clarity, femininity, divinity, delicacy, personality, modern, creation, anxiety
Orange	Persimmon, tangerine, carrot, autumn, leaves, evening glow	Pleasant, Satisfactory, Abundance, Lively, Healthy, Warmth, Friendly, Fresh
Black	Crow, night, darkness, briquettes, black hair, hair, tire, pencil lead	Anxiety, despair, sorrow, silence, solemnity, mystery, sophistication, frustration, death, fear, authority, vainness, despair, stoppage, negation, sin
White	Snow, winter, white clouds, lilies, white sheep, pigeon, swan, rabbit, wedding dress, sugar, milk, ice cream, nurse, angel	Cleanliness, purity, clarity, divinity, faith, light, hope, pure, noble, honest, simple

Table 2. Emotional Expressions for Colors

The association of colors is a kind of emotions caused by stimulating colors. It is influenced by personal life experiences and social and historical prejudices. What we reminiscent of color are large between individuals but socially universal reminiscent comparatively few individual differences. These common images among the associative images of various people have a role as a symbol of color. These color associative images can be applied to architecture. However, in the case of the red color, the abstract image which is conspicuous in the urban environment can be stronger than the abstract image such as love. Based on the main colors investigating the architecture facilities, domestic and overseas representation image, main material(dominance color), detailed material, architect, reference site, associated image for perform an auxiliary role in architect's color selection.









순번	건축이름	색상(색)	소재(재료)	유형(구)	소재(재료)	주소	대표사진
1	1.경복궁(종로) 동종축사(전사)	노란	재질	장암시암	내	서울특별시 종로구 종로 117	
2	2.서울특별시청	노란	재질	교후시암	내	서울특별시 중구 남산로 17	
3	3.동대문역사문화관	노란	재질	옥박시암	내	경기도 고양시 광명동 4062	
4	4.서울특별시청	노란	재질	후기시암	외	서울특별시	
5	5.동대문역사문화관	노란	유리	장암시암	내	서울특별시 중구 서울로	
6	6.425호실	노란	유리	장암시암	내	서울특별시 강남구 삼성동	
7	7.동대문역사문화관	노란	재질	석조시암	내	서울특별시 중구 서울로 117	
22	22 African American Museum	노란	양재	공회시암	외	Washington D.C., USA	
24	24 Red Oak Museum	빨간	재질	공회시암	외	Virginia	
28	28.역사문화관	빨간	재질	공회시암	내	서울특별시 중구 서울로	
32	32 Clear Blue Area(재용(인) 일)	빨간	재질	공회시암	외	교보빌딩	
44	44.아미노산 연구(연구) 센터	초록	유리	공회시암	내	서울특별시	
46	46.USA Entertainment	초록	유리	공회시암	내	영양사	
47	47 Gallery of Ensembles	초록	양재	공회시암	외	France	
48	48.한반도 국립공원	초록	유리	공회시암	외	영국, 미국	
50	50.South House	검은	고무	공회시암	외		

Figure 4. Exemplar Database Classification of Building Colors by Material Types and Façades

Architects can search for details and make supplementary use even after classification according to architectural use. In supplementary use, by use and by material, architects can draw images through examples, through a site that describes the examples you can find a more detailed description. Also through abstract vocabulary that given from color in the design start of the architect it has a great effect in emphasizing the aesthetics of the overall appearance of architecture through color. Color conditioning or color conditioning originated in propaganda terms originally used by DuPont in the United States, but is now settled in terminology. By defining the color control, it can be said that the safety and comfort of the environment is improved in the moving body which applies imitative colors to the buildings by positively applying the physiological and psychological effects of the colors. As a future study, after setting color modulation procedures, this research will suggest a usage guideline and library establishment proposal for the semipermeable multipurpose solar panel Building Information Modeling (BIM) for architectural industry field support. As a result, the analysis on type and elements of BIPV structures are set up clearly and establish the usage plan in the main field of the architectural industry including planning and construction field to attempt to make this into a

building material able to be distributed in the solar panel building market with the goal of a business model proposal aimed at popularization. The application possibility assessment will be done with the opinion of an on-scene specialist and through the analyzed information of the first year, the basic background of the second year is to attempt an objective and quantitative analysis. Many replacements of categorizing BIPV installation type was suggested and through this various forms of categorization was attempted to assess aesthetic formation and finally result in information that would become the basis for a business model needed for popularization. However, before the assessment, there is a vagueness in the categorization when making the survey and more precise separation is needed.

CONCLUSION

In this study, the color utilization index of BIPV including DSC and the database classification have been presented. As mentioned on the main chapter, the designer tends to try to meet the needs of the user through the detailed composition of the size and coverage area, and suggesting an auxiliary and a highlight color centering on the cast color through the ratio of each area are essential. The color satisfaction differs depending on the material regarding on the emotional image to be obtained through color. As a result of the study, the evaluation methods for color utilization were considered to be a rough and reliable test for the existing buildings. Therefore, it can be concluded that the color utilization analyses derived from the research can be meaningful in developing dye-sensitized solar cells having colors as well. And this study has searched to construct database including important parameters such as both performance and aesthetics from buildings, and it will make architectural designers possible to analyze integrative design performance for their buildings with working on. As an ongoing project, the following study will include library establishment proposal for the multipurpose solar panels using BIM for supporting fields of AEC (Architecture, Engineering and Construction).

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