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Utilization of Building Colors with the Energy-Oriented Algae Façade System

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ABSTRACT

Purpose: Building owners or residents have concerns to strive for energy-saving and environmental conservation by utilizing with eco-friendlier energy resources for their physical environment. In this paper, an algae façade system is proposed as an energy-friendly building component to improve energy productivity and indoor environmental quality, and this study aims at verifying alternative technologies for implementing building elevations that contain various colors equipped with algae façade systems and suggesting design guidelines to enhance both building performance and design values. **Method: T**he color of algae is basically ranged about the saturation green, and it is hardly converted to other variations. Such a problem can be resolved through the artificial lights like LED (Light Emitting Diode) lamps to mix the color from the algae and buildings could possibly change the elevation in many ways under the influence of daylight. **Result:** As a result, the suggested system may increase the aesthetic aspect of the building in response to environmental changes. The system cannot possibly be applied for only new construction, but also it can be utilized with the existing buildings as well. The proposed system is expected to be applied not only a new construction and any existing buildings as well, and it will cover from the environmentally friendly energy generation in the industry to a new application system for increasing energy efficiency and the beauty of building envelopes.

KEYWORD

Algae Façade
Building Colors
LED Lamps
Photobioreactor System
Building Envelopes.

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1. Introduction

Most of the current energy is dependent on fossil energy these days that is impossible for recycling and has disadvantages of causing environmental pollution, and the world is facing energy problems due to the depletion of energy resources. Currently, there have been various attempts and new trials for energy renewal technologies replaceable for fossil energy sources. Buildings also have given a lot of influences on the energy issue; actually, 40% of the energy consumption of the entire Earth and 35 percent of carbon dioxide emissions has occurred from buildings. [1]

Building owners or residents have concerns to strive for energy-saving and environmental conservation by utilizing with eco-friendlier energy resources for their physical environment. In this paper, an algae façade system is proposed as an energy-friendly building component to improve energy productivity and indoor environmental quality (IEQ), give flexibility elevation changes in aspects of the symbolism, and implement indoor settings and various spatial moods through the color effect of the building.

Nevertheless, the color of algae is basically ranged about the saturation green, and it is hardly converted to other variations. Such a problem can be resolved through the artificial lights like LED (Light Emitting Diode) lamps to mix the color from the algae and buildings could possibly change the elevation in many ways under the influence of daylight.

In this sense, this study aims at verifying alternative technologies for implementing building elevations that contain various colors equipped with algae façade systems and suggesting design guidelines to enhance both building performance and design values.

2. Theoretical Speculation

2.1. Algae as Promising Building Energy Resources

Algae cells are filled with oils into droplets that are regarded as promising rich resources. Since oils of algae cells can be converted into biodiesel and algae consume carbon dioxide (CO_2) during the culturing process, it is useful to use algae resources for improving the interior comfort with producing oxygen (O_2) by converting from CO_2. [2] Algae resources can normally be classified into macroalgae and microalgae. Macroalgae are well known as seaweed having multicellular organs raised from the seawater, and comparatively, the freshwater algae grow up to 60 meters in a singular form.

Microalgae have a unicellular organization and are grown

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normally in seawater. Freshwater environment makes microalgae grow fast just in the same way by cell division as macroalgae, and provides much nutrition to have enough strength. Oil production of microalgae is at least 100 times greater than that of soybeans. Optimal culture conditions according to these microalgae species are varied, and they can be selectively cultured in accordance with the national weather. [3]

Consisting of particularly invisible microalgae is superior to be applied to the building and advantageous for visual aspects towards façade systems. In eco-friendly settings, algae resources have a great possibility to harvest energy sources and relevant researches on the production technology are being performed in a variety of ways for the development of microalgae cultivation and application. [4] It is majorly divided into an open pond system and a closed photobioreactor system. Open pond system means an open culture, the cells of the algae in the tank in such a way as to depths of less than 30 meters to be passed well in the microalgae PV (Photovoltaics). [5]

Fig. 1. BIQ apartment complex in Hamburg (Source: Photo by IBA-Hamburg)

In general, this process is useful to generate a large scale in the form of energy, but it is necessary to maintain a constant temperature, when the difference in temperature is large, and so this system is difficult to apply. [6] On the other hand, closed photo-bioreactor system is cultured using transparent plate. Its biomass productivity shows 30-fold in average concentration that is much higher than open pond microalgae having 13-fold in average. Therefore, a closed photobioreactor system can easily be applied to the field of architecture and is a suitable algae system for buildings.

2.2. Energy Production with Algae Façade System

The building façade system is a factor that greatly affects energy saving and comfort of the building. Interior spatial environments such as light, air, heat, etc., give residents or users impacts on their health, and the indoor environment can be expected to play a role in the system to change the sensitivity.

Algae façade system applied with the tank system are formed as a part of the front windows and related with its cultivation. Solar culture and spatial usage can be diversified, the life of the building can be extended, and building energy cost can be reduced by both expanding supports for the aesthetic features of the building and implementing efficient components for performative configurations. [7] By applying the LED lamps in this system, building colors are shown into a variety of building elevations.

The use of photosynthetic microalgae helps solar energy be converted into chemical energies with storing in forms of oils, carbohydrates and proteins, and this process is one of the major advantageous technologies to reduce the formation of atmospheric CO_2. Algae are frequently found in damp areas or in water with small organs, from single-celled to multicellular that have different complex forms. Like plants, algae require mainly three components to grow: sunlight, carbon dioxide and water. [8] Microalgae can be told as fast-growing beasts with a voracious appetite carbon dioxide and have a potential to produce more oils per acre than any other feedstocks being used to make biodiesel. [9]

It can also be grown on land and is unsuitable for food crops. They are categorized into four main classes: diatoms, green algae, blue-green algae and golden algae. And, there are two main populations of algae: filamentous and phytoplankton. [10] Second-generation microalgal systems have the advantage that they can produce a wide range of feedstocks for the production of biodiesel, bioethanol, biomethanol and biohydrogen. Humans have always tried to take advantage of these properties through algal mass culturing.

It has been acknowledged that the concept of using microalgae as a source of fuel has been used for years. First, this paper will handle with the system overview producing microalgae. Currently there are three types of industrial reactors used for algal culture: photo-bioreactor, open ponds and closed and hybrid systems. In the production system, this research attempts to generalize the application of harvesting methods for microalgae. Then, analyses for optical reactors will be performed, and its reviews for overall concepts will include that how they work and manufacture optical reactor and charts showing the operation of the reactor. Subsequently, this study will analyze the open-pond systems in which algae farms were introduced in a raceway pond. In addition, the conclusion of this research will cover discussion about some general concepts of large-scale microalgal productions of biomass and improved methods for the implementation. [11]

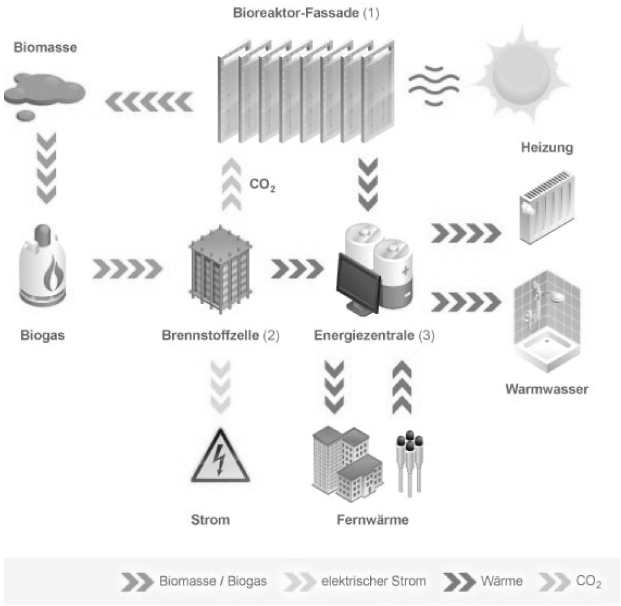

Fig. 2. Energy Production by the Algae Façade (Source: Kim and Han, 2014)

Then there will be detailed contents on the support of hybrid systems for the production of microalgae, referring to a number of outstanding issues as well as compared to other harvesting methods. An ongoing will introduce the concept of harvesting microalgae, the system structure for cultivation, and the pros and cons of each system. Based on these studies, it is expected to find a way to overcome the shortcomings of the system and improve old methods to guarantee their efficiencies as well as find out manufacturing methods to enhance productivity to lead the cost of microalgae to the lowest level for the future.

2.3. LED Lighiting towards Building Colors

Buildings color is one of major factors that affect human senses and the environment as well, has excellent strength of the stimulus than the shape and material, and has the influence to determine the image of the building. In addition, it makes the image and atmosphere of the city varied infinitely. Impacts of building colors also tend to be dependent on the situation and location such as country or region, and so, it is difficult to make a precise definition of color. [12] Even if only 5% of different colors used for building surfaces with the same mass form makes a feeling that buildings are different. Interior building spaces can also be varied and differentiated via a different set of colors.

The color of the seaweed is ranged about the saturation green. Colors with low saturation are often used for making dark images and not suitable for buildings. Low-saturated colors of the entire monochromatic settings of the building change the surrounding environment to boring or dark atmosphere, and such a problem can be resolved through artificial lights such as LED lamps to change the color from the algae; the building will change colors in multiple ways under the influence of daylight. [13]

The brightness by temporal variations to receive the direct sunlight can be changed actively and displayed vividly. And the degree of the change also varies depending on materials of the building façade. In addition, algae façade should have light-shielding properties by the color images and be applied in consideration of the characteristics of the exterior materials of the building. After combining the LED lamps with a transparent system of dopant, closed photobioreactor system may innovatively turn into new platform to support for both algae cultivation and color representation. [14]

Algae growth can be sustained through the LED lamps after all, and for example, a LED lamp making blue light may affect the reproduction of the plants and red lights able to affect the nutritional growth. Microalgae stay as a transparent plate to pass the natural light during the day, and carry out photosynthesis through the LED lamp at night. Also, LED lamps give aesthetic changes of the building mass by various color representations.

Fig. 3. LED lighting system for making color effects

Development of the LED lamp system in a uniformed shape to cultivate algae without affection by the natural environment is continuously performed as an ongoing project. The proposed system is expected to be applied not only a new construction and any existing buildings as well, and it will cover from the environmentally friendly energy generation in the field of AEC (Architecture, Engineering and Construction) to a new application system for increasing energy efficiency and the beauty of building envelopes.

2.4. Combined Color Systems for Building Surfaces

In order to apply this system, first, it is necessary to check in detail to the color change by building exterior material. Not only the color of the building exterior material, people of sensibility reaction takes place in accordance with the material. Buildings are usually limited to represent an image of pure colors, depending on

the material even with the same color, because they are going to another atmosphere and impressive. Building material is also a very important factor that can be varied to create a new building atmosphere.

There are suitable colors for the characteristics obtained from building materials, and they show differences among methods capable of representing the color. Thus, building exterior materials can be accurately represented by utilizing the necessary characteristics, and it is possible to know also representations in accordance with the characteristics.

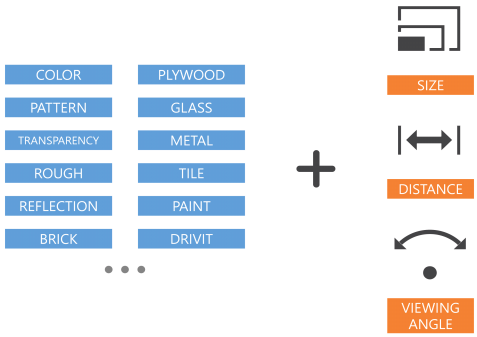

Fig. 4. Properties of the material towards building colors

Algae façade can obtain an effect of changing colors through the transparent plate. Transparent glass, so that the color displayed by the appearance in accordance with the reflectance and transmittance is changed. Thus, it is necessary to perform preliminary changes with the sunlight to building exterior materials. At this point, color selection is considered as the most important process because of the large impact when designing the appearance determining the image of the building. However, it is possible to obtain different results planned to be taken into the various elements of texture, and so giving positive relationship between building colors and material textures should be considered.

A myriad of changes may occur with major properties such as the area of the material and a sense of distance for a number of variables including viewing angles. If it is needed to apply the glass to algae façade, preliminary elevation design with reflectance and transmittance is always required. Glasses, especially, need variations for changing saturation and brightness depending on the reflectance and transmissivity.

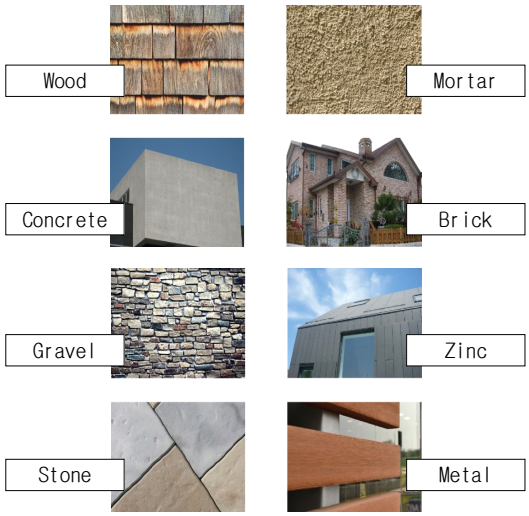

Fig. 5. Various exterior materials defining building colors

According to analysis results, reflectivity affects chroma factors and transmissivity tends to control the brightness. So, it has been turned out that building surfaces with high reflectivity and low transmissivity can be converted to low chroma with high brightness.

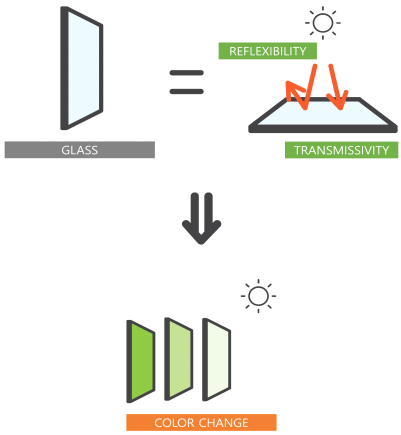

Fig. 6. Properties of the glass for making color effects

On the other hand, building elevations having exterior materials with low reflectivity and high transmissivity tend to show high brightness with low chroma. That is, the higher reflectivity is mixed, the lower chroma is obtained, while the lower reflectivity makes the chroma factor higher. And, the higher transmissivity is give, the lower brightness is gotten, while the lower transmissivity shows the opponent phenomenon. , The sensibility of the building surface can also be differentiated based on bothe reflectance and transmittance. Normally, in this notion, there are some terms related to reflectivity: perfect, modern, smoothness, and so on. Transmissivity is vividly related too.

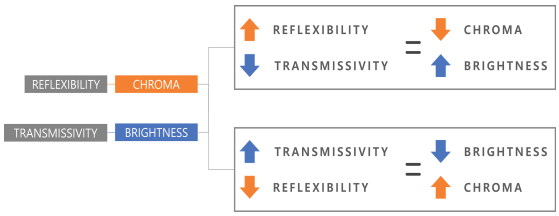

Fig. 7. Brightness and chroma contro; by lighting

3. Algae Façade towards Urban Moods

By applying the algae façade system and LED lightings to building surfaces as mentioned in the previous chapter, buildings in urban surrounding can improve the colorfulness and attractiveness. Otherwise, cities should consider for harmonized form among buildings, towns, regions and natures in aspects of the color.

Fig. 8. Local identity with color extraction

Currently, there is no any building design guideline for color planning in Korea and its difference is hardly found between cities and rural environments. Therefore, regional landscape with a cultural mood and building features do not match that much and the own characteristics of the area are often disappeared. In order to maintain the identity and cultural context of the existing area, it will be necessary to keep respecting the image and the culture of the own area in the stage of color planning.

In harmony with continuously surrounding environment, it will be possible to produce a space in accordance with the atmosphere of the region and the personality of the area can be survived. For, proper methods of accessing to and utilizing with the area color are inevitable for a successful design in order to take images and personality of the region accordingly.In the same elevation, it is needed to make a mixed condition among lighting, temperature and myriad changes according to humidity. Therefore, algae façade systems have to be applied to the surface with extracted regional colors that match the nature and microscopic climate of the area. City is, eventually, a target space that combines with a variety of building surfaces planned by color harmonization.

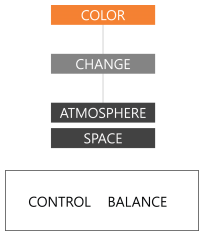

Fig. 9. Changes in urban moods by architectural colors

The color of the building also plays a role as a controller for the softness and an indicator for the feeling of the intensity regarding the city. Impressions to the building may be differentiated with about 5% color changes on the surface of the building and its alternatives will vary. In sum, building surfaces are able to produce a variety of urban atmospheres and spatial moods in way of color mixture.

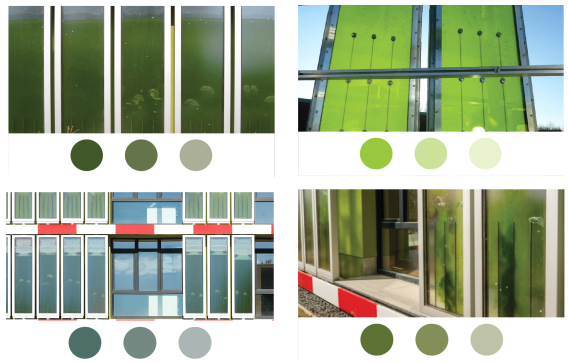

Fig. 10. Universal color of algae façade system

The color of algae is always green and they show low chroma and low brightness. Green color may give a comfortable feeling as one of neutral colors. However, because the color with low chroma like green is normally giving a dark image, converting it to any color with low brightness will make possible to give a heavier feeling. Further, green color consists of a feeling of dullness making an ambient environment in some cases. These problems with the color of algae can be resolved with utilizing LED lamps, and an ongoing research will include how to combine colors between algae and other LED lightings in order to consider for both improving algae growth in the enclosure system determining building performance and enhancing building surface design simultaneously.

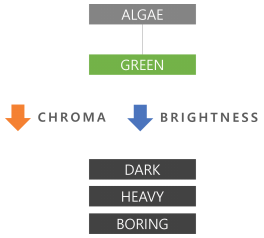

Fig. 11. problem-solving for color limitation of algae façade

4. Conclusion

In this paper, the algae façade system is proposed as a resolution for energy resource depletion and environmental degradation phenomena these days and alternative environmentally friendly energy resources presenting a new building component and its application system for both energy efficiency and the beauty of the building. This study tried to verify alternative technologies for implementing building elevations that contain various colors equipped with algae façade systems and suggesting design guidelines to generate proper colors with LED technologies.

To ensure environmental comfort and energy efficiency with algae resources, the façade system has been modelled to evaluate for building performance, and it is expected to be useful in improving human and natural environmental conditions as well. It has also been proved that the proposed algae façade system with applied LED lamp lightings produced the effect of infinite variation for the building surface and the various feelings shown inside the building too.

As a result, the suggested system may increase the aesthetic aspect of the building in response to environmental changes. The system cannot possibly be applied for only new construction, but also it can be utilized with the existing buildings as well. In this research, it is necessary to continue ongoing research on the growth of microalgae through LED lighting in order to improve the performance of the building and improve the design of the building. Microalgae are subject to many environmental influences, so research on what kind of environment is the most appropriate and how to make LED lighting useful for growing is necessary. Once the method of continuous growth is specifically set up, research on changes in the color of microalgae through LED lighting must be conducted. As mentioned in the text, microalgae have the original color, and new colors are created by mixing colors and colors. Therefore, in order to express suitable colors for each area, it is necessary to conduct researches for proper building color expressions with algae sources and their analyses from now on.

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