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A Futuristic Façade System with Kinetic-Algae Technologies towards Hanok

[Tae-Ryong Kim, Kyoung-Hee Kim and Seung-Hoon Han]

***Abstract*— The purpose of this study is to propose a new type of the building façade system towards Hanok, the Korean traditional residence. For this study, Kinetic-Algae technologies for the façade system have been amalgamated. Using a commercialized simulation program for thermal energy analyses, a façade system is proposed and its applicability has been verified. As a result, it is turned that the propounded system has a practically good applicability to the relevant practical field.**

Keywords*— *Hanok Performance, Integrated Comfort, Indoor Environment, Kinetic- Algae Technology, Façade System

I. Introduction

Recently, there has been huge demand of Hanok in Korean residential market. As resident lifestyle has changed, the Korean traditional residential building called Hanok is not appropriate for modern life. So there has been a huge movement in the field of market and inquisition. Many trials for styling new Hanok were attempted and relevant researches have been performed. In this circumstance, a modernized Neo-Hanok shows up. Neo-Hanok has both the beauty of traditional Hanok and amended space composition reasonably.

Figure 1. Diffference of Eave's Depth between Traditional Hanok (Left) and Neo-Hanok (Right)

Nonetheless there are something missed facts in Neo-Hanok; traditional Hanok has normally long depth of eaves, while notwithstanding Neo-Hanok has various types of eaves as shown on Figure 1. This change can affect Hanok's performance significantly.

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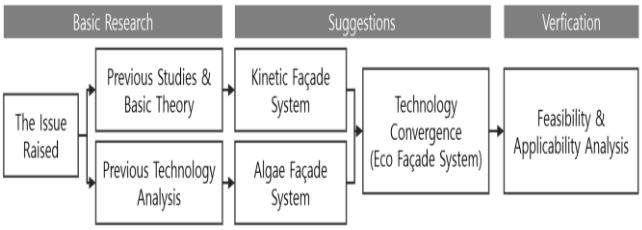


Figure 2. Research Scheme

For example, in traditional Hanok, long eaves act like a horizontal louver that prevents direct radiation in the Summer season. Therefore, additional façade system would be needed to guarantee the same performance towards Neo-Hanok. The ultimate goal of this study is to suggest a new façade system for Hanok having short eaves and its controlling system.

To build the control system for the proposed façade, the previous study of indoor comfort performance evaluation system[1] was investigated. Through the step shown on Figure 2, this study suggests a kinetic façade and its controlling system utilmately.

II. The Concept and Theory of the Algae Technology

A. *Introduction of Algae Technology*

The research about algae popularization has been performed since 1980s but did not draw much attention because of some known problems in aspect of inadequate status in economy. However, this technological concept is taking attention again recently as people become more interested in eco-friendliness and renewable energy and now related researches are being carried out by mainly western countries.

Algae technology is a photosynthetic organism that produces biomass using light and CO_2 in aquatic environment. Algae are largely classified into macroalgae and microalgae. Macroalgae are mainly known as seaweed and is a multicellular organism that grows up to 60m fast in seawater or fresh water. Compared to this, microalgae are utilizing unicellular organism in the unit of micrometer and also grows in seawater and fresh water environment just like macroalgae, and reproduction by nutritive cells can be fast.

[1] T. Kim, K. Kim. and S. Han, "Implementation of Intelligent Pre-Occupancy Evaluation for Hanok Performance," Proceedings of AABES 2015, 2015.

Researches for algae technology until now are mainly composed of basic researches such as characteristic development of various species and effectors' development, however, for the commercialization in the future, high-quality algae cultivation technology and its establishment for wide-scaled biodiesel refinement is quietly needed (Ministry of Education, Science and Technology, Bio-energy Production Technology Using Algae, 2009).

The reason that technology with solicitude of economy establishment due to lack of core technology until now has a big potential as eco-friendly building materials can be found in the production process and cultivation system of algae fuel. If we take a look at production system of algae fuel, improvement of indoor air quality can be obtained by consuming CO_2 and changing it to O_2 in the cultivation process, and moreover, water tank facility for algae cultivation is quite obliging for confidentiality improvement of overall building because of its high specific heat.

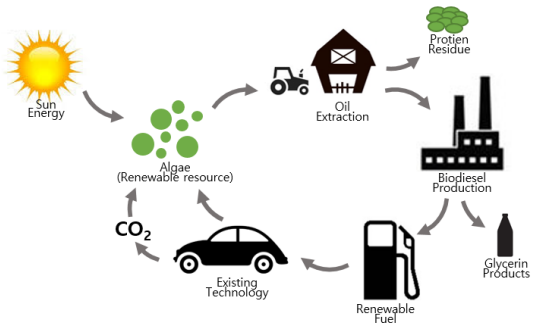


Figure 3. Process of Algae Fuel Production
(Source: Biolectric, Inc.)

B. *Application of Algae Technology*

According to prior researches of Christi (2007), microalgae are known as better one in the aspect of energy production among two types, and since it is made of invisible small cells, the water around it tends to be sustainable while macroalgae contain visible floaters. Thus, considering the energy production aspect and visual points of building based on facts above at the same time, the general opinion can be told that it is proper to apply microalgae to the building.

C. *Technology Application Method*

Numerous methods are being developed as cultivation method for microalgae and the following two methods are the ones used mainly currently.

A. Open Pond System

Open pond system is a structure that the form of lanes opened to the outside is connected and a system that algae cells and nutrients are mixed then circulated by paddle wheel. Habitually, baffle is installed to save the space in perimeter. This system produces energies based on the solar resources, so it is general to constitute with the depth below 30m so that light penetration is good for delivering sunlight to microalgae is very substantial.

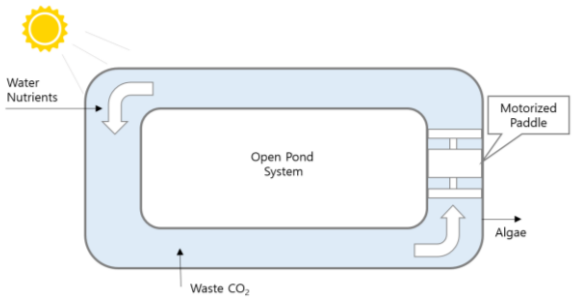


Figure 4. Concept of the Open Pond System

This technology has been researched by DOE (Department of Energy) for a long time as a cultivation method for microalgae and the form of algae fuel farm is generally made in large scale in outer space. This system has its fragility in that it has much moisture loss by evaporation though installment cost and operation cost is cheap, and CO_2 supply is inefficient. Moreover, keeping a stable temperature is quite crucial to maintain the amount of highly efficient energy production and this is quite hard to apply to the condition for our country, where we have extensive temperature gap between quarters.

B. Closed Photo-biological Effectors' System

As shown on Figure 5, close photo-biological effectors' system uses transparent conduit that grows microalgae in the water by supply of CO_2 and nutrients as well as light penetration and is one of the most capital-intensive systems. This system is generally installed outside in order to utilize natural sunlight irradiation. The advantages of photo-biological effector include that cultivation conditions can be controlled undoubtedly, there is no moisture loss due to evaporation, and contamination from the surrounding environment can be prevented. Especially, biomass efficiency of closed photo-biological effectors' system is higher 13 times than open pond and the concentration of biomass is higher by 30 times, thus production efficiency seems more excellent compared to yield cost.

Cultivation effector is designed to have large surface in comparison to its volume and the form that many transparent tubes are connected is most widely used for the structure. The diameter of the tube is usually below 10cm to enable sunlight and to penetrate at its maximum level. Cultivation medium is circulated within the tube by pump and microalgae grow by photosynthesis, for it is exposed to the light.

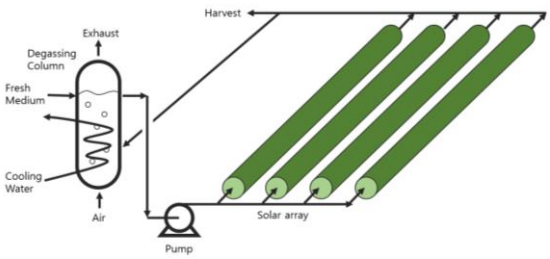


Figure 5. Conceptual Diagram of the Closed Bioreactor System
(Source:Y. Christi, 2007)

Oxygen is generated in the process of photosynthesis. In open lane system, it is not a problem that oxygen is emitted to the atmosphere, however, in the close system excess

oxygen should regularly be removed for oxygen more than a certain concentration within cultivation medium that can depress the growth of microalgae. Likewise, since CO_2 is used in the growth of microalgae, CO_2 should continuously be supplied so that PH level will not go up or carbon will not be depleted and temperature must be maintained stably with that of night by cooling it while daylighting[2].

C. Technological Method and Application Scope

Judging on this basis, closed photo-biological effectors' system can be said appropriate as method to apply algae to the building. Furthermore, it is judged that using the whole surface of windows and doors instead of conduit of pipe shape as lane form to actively transform water with highly specific heat to building energy upon usage in the building would make better efficiency.

Figure 6 is a precedent of algae façade in Hamburg, Germany. We cognize from the case that it has an overall lane form instead of conduit form, and this structure is the one that specific heat of lane can be utilized at the maximum level. Thus, this research as well conducted experiment targeting the analysis model that algae façade of overall lane form was applied to building façade.

Figure 6. A Case Model for Algae Façade in Hamburg, Germany (Source: International Building Exhibition)

III. Algae-Applied Façade System towards Hanok

A. *Basic Theories for the Shading*

Shading system is an element for controlling the solar radiation to adjust an indoor environment. This component is normally fixed on the wall and unable to control the solar radiation effectively. In addition, a fixed vertical louver interferes for the outside views. So, a type of moveable louver seems available to be activated for the building façade in order to resolve mentioned problems.

On the other hand, a light shelf is an architectural element which allows the daylight to penetrate into the indoor space as deep as possible and blocks the direct sunlight to prevent a glare. This type of the shading system has been proven to decrease the artificial lighting consumption quite much. Thus, it improves the visual comfort to occupants, and may reduce cooling loads by blocking the direct sunlight.

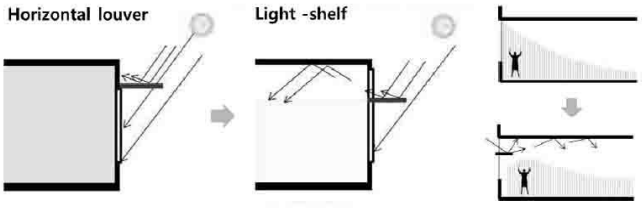


Figure 6. Comparison of Horizontal Louver and Light Shelf [3)]

As an advanced type of shading system, kinetic façade system is an active control system for making better indoor environmental condition by changing its function according to the exterior surroundings. This system is designed to move partial components for responding to environmental changes outside. As a rent time, practical implementations of the kinetic system are being realized with advanced technologies in mechanics, electronics and robotics, while those still have considerable problems in aspects of production and maintenance costs, in as much they require tight collaborations among various fields

B. *Application of the Algae Technology for the Kinetic Facade*

This study proposes an eco-façade of the modular system applied with integrative functions of vertical kinetic louver and algae façade. The suggested system can change the shape by the position of the sun. This unique combination has the distinction from the existing kinetic façade systems.

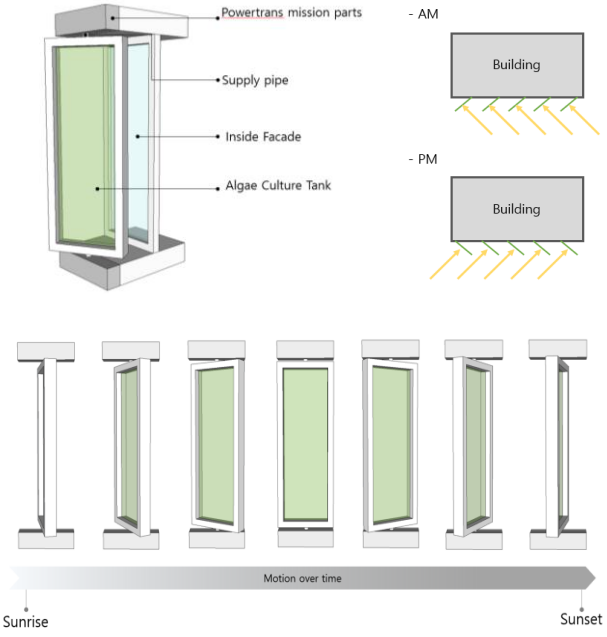


Figure 7. Funtion Changes According to the Altitude of the Sun

Two comparative functions such as penetrating natural daylight and blocking the solar radiation are embodied and optimized into the system, and the proposed mechanism has provided to support relatively enhanced environmental controls.

[2)] Ministry of Education, Science and Technology, opcit., pp. 80-81

[3)] O. Im, A Study on the Kinetic façade system and the energy performance evaluation of KLSU system, 2014, p23

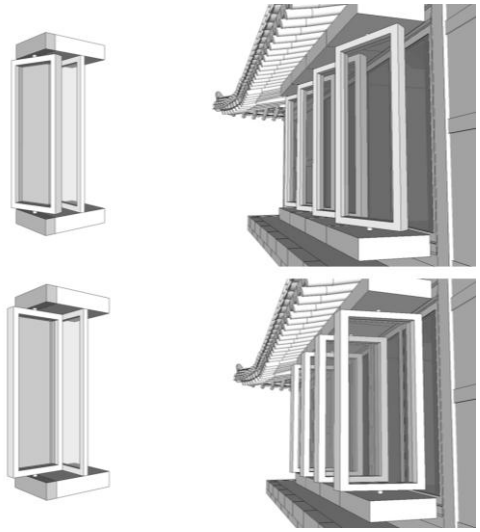


Figure 8. Proposed Eco-Façade System for Hanok

C. *Thermal Performance of the Proposed Eco-Façade System*

With conducting the energy simulation, thermal data are essential. Especially, the research of the thermal performance of the algae façade was almost hard to find because they are not commercialized. Figure 8 is an experiment conducted at the University of North Carolina in the U.S.A and recorded thermal energy distribution grasped using infrared camera by producing mock-up for algae façade. In the result of this research, algae façade was shown to have same energy efficiency as Low-e Coated IGU (Insulated Glass Unit).

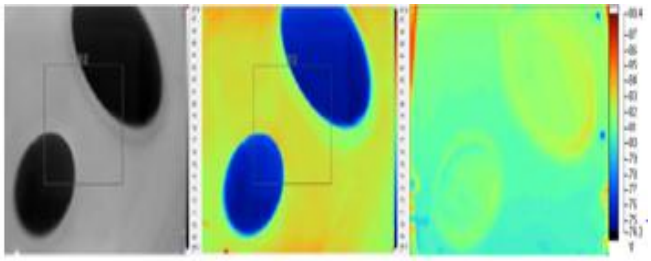


Figure 9. Thermal Performance Output for Algae Façade

Ecotect Analysis by Autodesk was used as an energy analysis tool and Table II shows the outlines of the analysis from energy simulations. As a result, 6% reduction in aspects of energy consumption per year was concluded from the simulations.

TABLE II. OUTLINES OF SIMULATION SETTINGS

Category	Contents
Buildings	Virtual Building Modeling with basic properties of Hanok
Weather & Location	Gwangju, Korea,(latitude : 35.1, Longitude 126.9)
Size	70.6m^2 × 3.3m
Opening size	W:4,200mm H:2,000mm. W:3,300mm H:2.000mm
Orientation	South

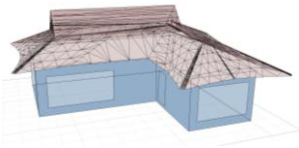
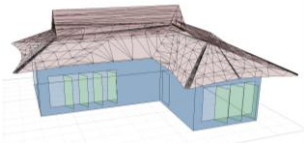
Simulation Method	Ecotect Thermal Simulations					
Properties	Slab		Wall		Roof	
	U-value	0.88	U-value	0.17	U-value	3.1
	Admittance	6.0	Admittance	4.380	Admittance	3.1
	Solar Absorption	0.467	Solar Absorption	0.231	Solar Absorption	0.6
Target Models for Simulation						
						
Normal Hanok			Hanok with Eco Facade (Based on Hourly Form Changes)			

TABLE III. HEATING AND COOLING LOAD

Type	Monthly Load (Wh)					
	Month	Heating Load (Wh)	Cooling Load (Wh)	Month	Heating Load (Wh)	Cooling Load (Wh)
Normal Hanok	Jan	1750616	0	Jul	0	342865
	Feb	1312942	0	Aug	0	412764
	Mar	925452	0	Sep	0	186122
	Apr	419860	0	Oct	0	0
	May	105455	0	Nov	186191	0
	Jun	0	64179	Dec	701257	0
	SUM	7,806,748				
Hanok with Eco Façade	Jan	1692723	0	Jul	0	250894
	Feb	1272487	0	Aug	0	309687
	Mar	900690	0	Sep	0	121669
	Apr	411284	0	Oct	202690	0
	May	126479	0	Nov	681576	0
	Jun	2285	14752	Dec	1354962	0
	SUM	7,342,178				

IV. Conclusion

The purpose of this study is to suggest an eco-façade system for Hanok and Neo-Hanok. To suggest this system, both algae technology and kinetic façade system were used. Through the final step of this study, composition of the proposed eco-façade system can be verified for the adaptability of its energy performance by a thermal energy analysis tool. The simulation result shows 464,570 Wh energy savings and this is equivalent to 6% of the total energy consumption of the normal Hanok.

In conclusion, this study has suggested an ideal eco-façade system and their controlling methods. Merely there are still some issues to be resolved; the proposed kinetic-façade system was simulated in limited range and the simulation contained only hourly movements of the façade system. Consequently, some factors may be missed such as human reactions etc. due to technical limitations of the

simulation tool. In this sense, an additional simulations for human behaviors are being performed under active researches and relevant analyses should be followed for further researches.

Acknowledgment

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