AN INTEGRATIVE PROTOTYPE MODEL FOR CONTAINER SPACE MODULE AND ALGAE FACADE SYSTEM

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Abstract- In this study, problems scattered in the building sector were picked up, using the method of applying Algae Façade to the structure of container. As a first step, analyzed the transition of energy performance by fusing container construction and algae system and considered the possibility of application. More than 10 cases were analyzed, the optimum outer skin composition was selected, and the composition of the fittings was decided based on the building law and recommendation. By applying this, energy performance analysis of various combination types of containers was carried out. Comparative analysis was made between cases where the known Façade was applied and cases where normal fittings were applied. This study aims at investigating the adaptability towards the future sustainable building with algae technology and testifying the energy efficiency of the algae skins by operating a couple of simulation tools to measure building performances for the proposed prototype of the façade system.

Index terms- Container architecture, Algae system, Energy performance, Technology integration.

I. INTRODUCTION

To date, the interest of houses was mainly the construction of 3 to 4 households and the center of apartment, but recently one household has shown a sharp increase trend, a new floor plan and construction system is necessary. As a major problem that can't overlook energy problems, in the past, in the case where research on energy conservation was the main focus, research to produce energy voluntarily in each field is actively underway.

In this study, problems scattered in the building sector were picked up, using the method of applying algae façade to the structure of container. For that purpose, it is important to generate synergistic effects by fusion of technologies rather than making solutions with one technology. In this research, recently, it began with interest in container construction which expanded its range to housing complex, housing, dormitory, cafe and other complex facilities. The structure of a container clearly different from the existing building system has a unique appearance at a glance, and it has various features such as a construction method, an internal configuration, a unit price, and the like.

What kind of shape and system should be applied when applying the unique energy production system of these container constructions? Also, how much performance should you demonstrate in terms of energy? What should we do to provide more versatile functions? In order to find the answer to the question of and, the following research is necessary.

Firstly, unless research on the specialty of container construction is accompanied, secondly, research on the principle of Algae System to be applied and applicability to Façade is necessary. Third, it is the method of technology fusion. In this paper, representative types by number of combinations of containers were selected for eight cases, and the difference in energy performance when general fittings and Algae Façade were applied were compared and analyzed.

II. THEORETICAL BACKGROUND

1) Container Construction

Container, the main component used for container construction, is a box-shaped container welded with durable steel manufactured for safely transporting cargo. This container regulates the structure and strength so that permanent repetition can be used, and it is excellent in durability. Just because of these characteristics, containers can be used as building materials.

The container structure can be divided into two according to the container supply and demand method, the first is the method used to build the old shipping container and the second is the method of manufacturing at the factory for the use of the building. Both methods require further insulation, electricity, water, and other processes for use in residential and commercial facilities. And both of all has features such as reusing materials, using the structural strength of the container itself and ease of maintenance by standardized size.

2) Algae Technology

Algae is a photosynthetic organism that produces biomass utilizing light and carbon dioxide in an aquatic environment.

Unlike food crops and woody biomass, it is clear that certain algae have the function of producing and accumulating naturally oil by photosynthesis, it is one of the most influential resources for production of algal biofuels has emerged rapidly.

Algae technology has the following features.

Firstly, breeding is quick and second, the area required for foam is 30 times less than what is necessary to cultivate other plant resources. Third, control of production process and product quality is easy. Various methods have been developed for culturing the microalgae, basically it is classified into two types, an open pond system and a closed photobioreactor system, and according to each system, advantages and merits have disadvantages.

3) Technology Integration

First of all, the current state of technology at present is grasped for fusion of technologies, and concrete implementation method was proposed.

Estimated result of Korea's renewable energy amount in 2020 Solar power generation 552,000 TOE, wind power generation 2,035,000 TOE, bio energy 4,211,000 It was found that the possibility of bioenergy development is quite high in TOE. Among them, the production of bioenergy using seaweed belongs to the low rank of 907,000 TOE, but its growth rate ranks first among 49.6% from 2008 to 2030.

In terms of production volume it possesses the world's fourth-class infrastructure and technology, and it has conditions suitable for applying Algae Fuel. And the possibilities of Algae Fuel have already been demonstrated in developed countries like Germany, Brazil and Japan.

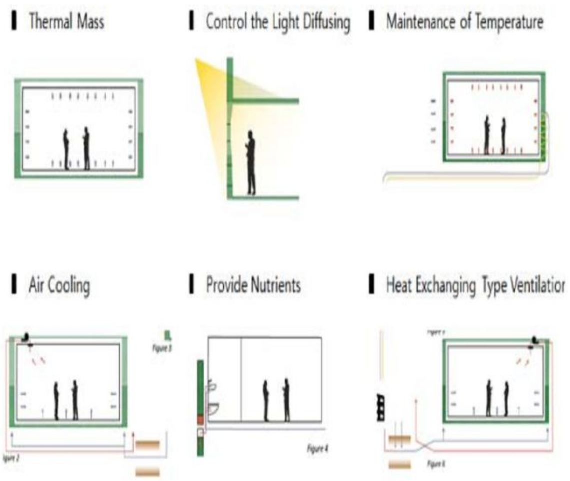


Figure 1: Applied to building of Algae system

On the other hand, the container structure is typically made by reusing lung containers used for cargo transportation, and it is sometimes manufactured for use in field offices, shops, and toilets.

These container structures are accurately unitized according to standards, and their deformation and combination are easy, and the construction term can be shortened through prefabricate. Also, its structural stability and durability is an advantage that it can be obtained as it is built. Thanks to the construction of the container, which is a combination of structural frame and panel, various elevation and spatial configurations can be created via panel change.

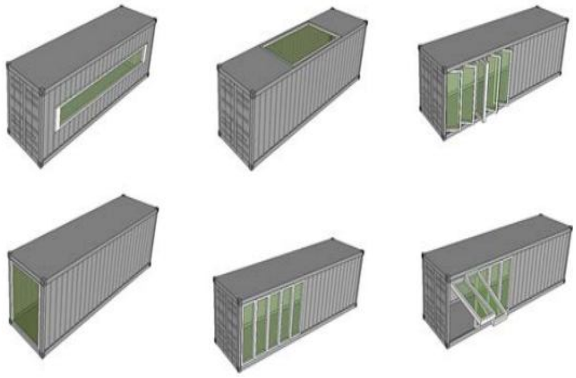


Figure 2: Applied to container of Algae façade

Against this background, the elevation of container construction is replaced by Algae Façade, various modules are created, and energy efficiency is grasped through simulation.

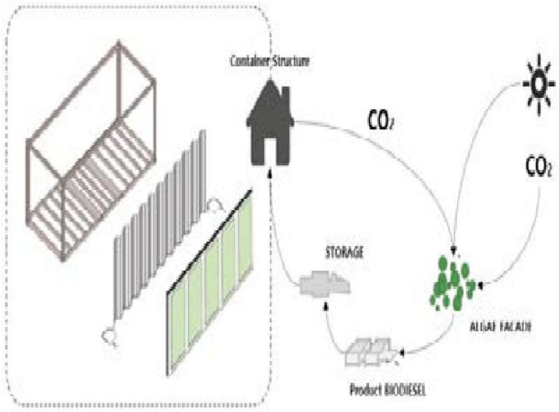


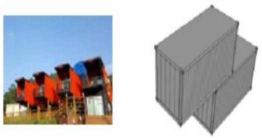
Figure 3: Container and Algae façade fusion concept

III. SIMULATION METHOD

Based on the eight cases for simulation, the type of combination of containers, representative type of ceiling, wall, floor and representative type of windows were set.

Table 1: Container combination example

Case 1 	Case 2 
Case 3 	Case 4 

Case 5	Case 6
	
Case 7	Case 8
	

It analyzes the energy performance displayed when combining the two most basic containers, selects the result value as a representative type, and shows the difference when applying the following general glass and Algae Façade It will be analyzed.

1) Container Combination Type

When two containers are combined, five types can be confirmed, and it can be divided into one-story type and duplex type. Various forms can be confirmed according to the design, but five types are typically revealed.

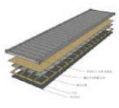
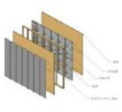
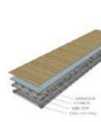
Table 2: Representative type of container

Type ①	Type ②	Type ③	Type ④	Type ⑤
				

2) Representative Type of Ceiling, Wall and Floor

Types of representatives according to the composition of the ceiling, wall and floor are as follows and the most efficient configuration was chosen.

Table 3: Representative type of container construction

	Representative type	Information	
Ceiling		•Iron bending panel •Polyurethane foam •50 mm glass wool •Squared timber 50*50 •3 mm gypsum board •Ceiling finish	•overall thickness: 77.2 mm •Thermal resistance: 1.905㎡k/W •U-Value : 0.52W/㎡k
Wall		• Iron bending panel •18 mm plywood •30 mm styrofoam •Wakamatsu square material 30 * 30 •3 mm plywood •Wall interior finish	•overall thickness: 58.4 mm •Thermal resistance: 1.533㎡k/W •U-Value : 0.65W/㎡k
Floor		•Iron bending panel •50 mm extrusion method thermal insulation board •hot water ondol heating •Wood crate plywood floor	•overall thickness: 56.2 mm •Thermal resistance: 1.849㎡k/W •U-Value : 0.54W/㎡k

3) Typical Window Type

In order to set the representative type of the fittings, reference was made to "Guidelines for Fittings for Energy Conservation of Buildings" published by the National Land Department.

In the case of the southern region of South Korea, southward orientation is the most advantageous from the viewpoint of energy requirements of buildings when applying windows of legal level (40% window area ratio), the trend of northward > eastward > westward.

Therefore, in the experiment, the ratio of the wall and the window was set to the southward window 40%, the northward window 40%, and the basic value of the triple glass was applied to the performance of windows.

Table 4: Performance factor of windows

	Performance factor of windows
U-Value	0.75
SHGC	0.45

4) Algae Façade

In order to know the physical performance of fittings with Algae applied, experiments conducted at the University of North Carolina in Charlotte, USA were helpful. This is a measurement of thermal energy efficiency with an infrared camera after making Mock-up of Algae Façade. From this experimental result, Algae Façade was found to have energy efficiency equivalent to Low-e Coated IGU (Insulated Glass Unit).

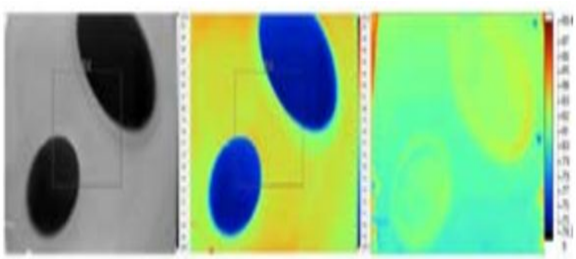


Figure 4: Algae façade thermal performance output (Source: T. Kim, O. Lim, S. Kim and S. Han, 2014)

Table 5: Performance factor of Algae façade

	Low-E Coated IGU
U-Value	0.29
SHGC	0.27

IV. RESULT OF SIMULATION

In each simulation, the composition of the representative material of the ceiling, the wall, and the floor of 3.2 is similarly applied based on the combination type of the container of 3.1, the property value of the fitting representative type of 3.3 and the property value of Algae Facade of 3.4 are applied, And compared with each other.

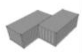
Table 6: Performance factor of windows

CLIMATE INFORMATION	LOCATION	GWANG-JU, SOUTH KOREA
	AVERAGE TEMPERATURE (℃)	20.0
	DIRECTION OF BUILDING	MAKE WIDE SIDE TO SOUTH
DEFAULT SETTING	BUILDING TYPE	RESIDENCE
	HEAT SOTRAGE (Wh/ m^2K)	60
	HEATING TEMPERATURE (℃)	20
	COOLING TEMPERATURE (℃)	26
INTERNAL HEAT GENERATION	RESIDNETS	2
	INTERNAL HEAT GENERATION (W/ $m^{2)}$	4.38
VENTILATION	HEATING EFFICIENCY	71%
	COOLING EFFICIENCY	71%

5) Application of Triple Glass

First, it is known that the energy capacity decreases as the outer cover area increases, and as the outer cover area becomes wider, the heating energy demand increases widely, but on the contrary, the cooling energy requirement shows a slight difference.

Table 7: Application to triple window glass Simulation result

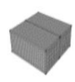
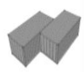
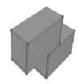
	①	②	③	④	⑤
TYPE					
OUTER COVER AREA (㎡)	66.3	81.9	82.8	100.3	100.3
HEATING ENERGY DEMAND (kWh/㎡)	143.34	165.33	168.69	190.16	190.41
COOLING ENERGY DEMAND (kWh/㎡)	58.02	57.99	57.39	57.58	58.09
ENERGY PERFORMANCE (L/㎡)	14.3	16.5	16.9	19.0	19.0
ENERGY COST (KOREAN WON)	689,800	733,000	738,700	781,100	782,400

In addition, although not explained in the paper, it can be seen that as the number of combinations of containers increases, the value of the outer skin area increases, and the heating performance improves accordingly. This seems to be due to the increased number of containers used and to naturally expand the internal space.
As a conclusion, the amount of energy loss is the smallest when combining in such a way as to reduce the outer skin area to the maximum, and the difference decreases as the number of containers increases.

6) Application of Algae Façade

Comparing general triple glass and Algae facade, heating energy requirement increased by 4.04 kWh / m2 based on type 1, whereas cooling energy requirement decreased by 14.18 kWh / m2.

Table 8: Application to Algae facade Simulation result

	①	②	③	④	⑤
TYPE					
OUTER COVER AREA (㎡)	66.3	81.9	82.8	100.3	100.3
HEATING ENERGY DEMAND (kWh/㎡)	147.38	169.64	173.04	194.77	195.00
COOLING ENERGY DEMAND (kWh/㎡)	43.84	44.07	43.59	43.97	44.40
ENERGY PERFORMANCE (L/㎡)	14.7	17.0	17.3	19.5	19.5
ENERGY COST (KOREAN WON)	678,500	722,400	728,300	771,400	772,500

This is because the transmittance is lowered, the acquisition of solar radiation decreases (SHGC: 0.45 → 0.27), the heating energy demand increases, whereas the cooling energy demand relatively decreases. For this reason, the overall energy performance increased to 14.7 L / m2 at 14.3 L / m2, but the energy cost decreased from 689,800 won to 678,500 won per year.

CONCLUSION

This paper is an analysis of the transition of energy performance displayed when the container construction and Algae system are merged. Based on the eight cases, the optimal outer skin composition was decided, and the composition of the fittings was decided based on the building law and recommendation. By applying this, energy performance analysis of various combination types of containers was done.

The simulation compares the case where algae facade is applied and the case where normal window is applied, and the result is as follows. First, the amount of energy loss is smallest when combining in a form that reduces the outer skin area to the maximum, and as the number of containers increases, the difference decreases. Second, heating energy demand increases when comparing the triple glass window with Algae facade, whereas the cooling energy requirement decreases. This is because the transmittance decreases and the solar radiation acquisition amount decreases. Third, since the adiabatic value of Algae facade is higher than that of general fittings, cooling energy demand remarkably lowered and showed a monetary advantage.

In conclusion, algae facade has low transmittance due to algae inside the facade and can reduce loss to some extent with high adiabatic value instead of reducing solar radiation acquisition. If the algae system that will produce energy is applied to the facade, we can expect a highly efficient facade. In this paper, since only the adiabatic value of glass and SHGC value are taken into account in the aspect of energy performance analysis, it was possible to obtain fragmentation result values. Considering not only the performance of the glass but also the performance of the fittings, even more significant results will be obtained.

ACKNOWLEDGMENTS

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