PERFORMANCE INDEXES AND EXAMINATION METHODS OF TRANSPARENT SOLAR CELLS ON THE BUILDING FAÇADE

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Abstract - The Purpose of this study is to search for a measure of the BIPV (Building Integrated Photovoltaics) performance index and to search for a test that can be used to determine the BIPV's performance index. The research method derives the performance index through searching the window performance index of the previous research and find important values of the performance index through the analysis of the test related to the derived index. After examining the tests to be able to measure them, this study examines whether the test is meaningful to the BIPV through the feasibility study. As a result of the study, the performance evaluation methods such as thermo-graphic camera and blower door test were considered to be a rough and reliable test. Therefore, it can be concluded that the performance evaluation tests derived from the research can be meaningful in measuring the performance of BIPV.

Index Terms - Blower Door, Performance Index, Transparent Solar Cells, Thermo-Graphic Device

I. INTRODUCTION

It has been a long time since the BIPV (Building Integrated Photovoltaics) applied to buildings. In particular, BIPV was used extensively on the skin and roof of the building. And the effect of using BIPV is also increasing. However, as part of the building skins of architectural design, the BIPV still reveals its vulnerability. Due to the lack of aesthetic parts of the BIPV, it is not easily used on the architectural design of buildings. But BIPV is one of the elements of the skin component such as glass and paint. BIPV has performance in both quantitative and qualitative aspect. Like this, BIPV is still a difficult material for architectural design. Therefore, BIPV requires a unique evaluation method to review performance. Exploration of the index is the first prerequisite for the preparation of the BIPV using.The purpose of this study is to explore the performance of the BIPV compared to existing building materials and to find a test to measure the unique performance indexes of BIPV. Furthermore, it is also included to find the measurable test for space performance when the BIPV is used in space.

II. SCOPE AND METHOD OF RESEARCH

This study was carried out on transparent BIPV instead of commercial BIPV. Conventional BIPV does not belong to transparent materials such as glass and acrylic, so it cannot have a great influence on the formation process of the architectural design. In addition, the existing BIPV is already have quantitative performance evaluation. And, Transparent BIPV is currently under development. Therefore, the range of the performance index can be changed depending on the future change. The evaluation index of transparent BIPV is more likely to replace glass in terms of usage, and it is necessary to have glass performance. For this reason, the study was conducted based on the quantitative performance of glass as a criterion for evaluating the selected BIPV. The research process was carried out in four procedures. In the first step, investigate the performance indicators that should be used as performance indicators of existing windows. In the second order, the most standard of the tests that can be evaluated for this was the performance evaluation test of the KS (Korean Standard). The third step is to search for significant indicators in the BIPV among the indicators presented in the above tests and examine whether the indicators are applicable to the BIPV. Finally, this study utilized information on other performance tests that can roughly confirm the meaningful performance indicators derived from this, and confirmed the feasibility of performance tests that can easily confirm the performance indicators and the applicability to BIPV.

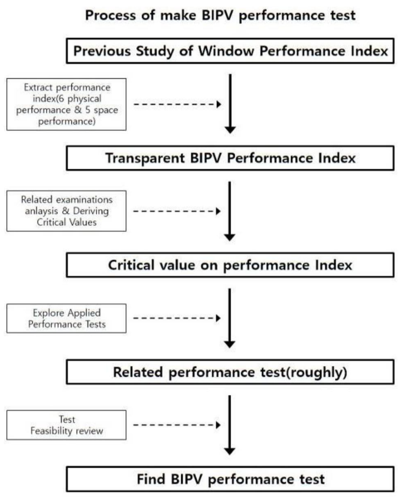

Figure 1. Process for Finding Performance Test Methods

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III. DETAILED PROCESS OF TRANSPARENT BIPV PERFORMANCE TEST

A. Exploring Performance Index through Window Performance

The quantitative performance indicators of windows are divided into two categories: physical performance of windows and spatial performance of windows installed. In the case of space performance using windows, there is no specific space criterion. Therefore, the performance is deduced from the values such as room temperature and window surface temperature which can be measured in the field. Therefore, spatial performance has a lower priority of review than physical properties that can be identified by specific tests.

The physical properties of windows have 'sustainable' performance such as durability, waterproof, abrasion resistance and 'protecting' performance such as insulation, water resistance and airtightness. 'Sustainable' performance may vary depending on the material, shape, installation location, etc., but 'protecting' performance must have certain criteria due to the characteristics of the use. Transparent BIPV is still in the development stage. So, shapes and materials can change depending on future developments. Therefore, 'Sustainable' performance may be difficult to apply to BIPV or the measured performance value may be meaningless. Considering the characteristics of window performance mentioned above and the current situation of BIPV, 'Protecting' performance is more suitable for the search of Transparent BIPV performance indicator. As a result, the performance of the transparent BIPV has been specified as the performance of insulation, water resistance, airtightness, sound insulation, condensation resistance performance, wind resistance performance and structural performance. In the case of the space performance index, the five parameters of the existing window performance indexes: thermal environment, light environment, indoor atmosphere, sound environment, and energy performance are specified.

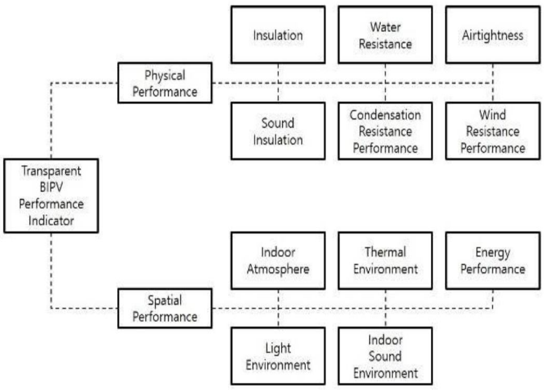

Figure 2. Performance Indicator of Transparent BIPV

B. Investigation of Domestic Standard Specification Performance Test & Deriving Critical Factors

Most of the above-defined transparent BIPV performance indicators are classified into Korean Industrial Standards, so each item can be evaluated through performance tests. The Korean Industrial standards refers to a standard approved by the national government. If you look around the world, it is widespread to investigate the ISO (International Standard Organization) standard instead of the Korean Industrial standards. However, considering the characteristics and easiness of Korea's industrial standard, this study used the test written in the Korean Industrial standards, excluding the international standard ISO. There are six types of tests that can be applied to the performance index of transparent BIPV.

KS Standard Number	Standard Name
KS F 2278	Standard test method for thermal resistance for windows and doors
KS F 2292	The method of air tightness for windows and doors
KS F 2293	Test method of water tightness for windows and doors
KS F 2294	Test method for Structural performance of exterior windows
KS F 2295	Test method of dew condensation for Windows and doors
KS F 2296	Window & door tests and wind resistance test

Table 1. Window Performance Tests Defined by KS

However, in addition to the above items, the related performance tests are also classified in detail according to the conditions such as field measurement method, use of special substrate

KS Standard Number	Standard Name
KS F 2235	Field measurements of sound insulation of building façades and façade elements
KS F 2606	The methods for water resistance of exterior wall boards in building
KS F 2829	Thermal performance of buildings - Qualitative detection of thermal irregularities in building envelopes - Infrared method

Table 2. Façade Material Performance Tests Defined by KS

Among the various related performance tests defined above, the performance test methods, devices, and important factors derived from the tests were analyzed based on the six tests mentioned in Table. - KS F 2278 Test: The purpose of this test is to determine the insulating properties of the members under the restricted conditions to classify the grades. The test equipment consists of a 2,000㎜ x 2,000㎜ opening between the thermostatic chamber and cold chamber, and a protective heat box, a cold air blowing device and a measuring device inside the low temperature chamber. The configuration of the test apparatus is shown in the figure below.

Because of the measured value is the temperature, the temperature in the chamber and the thermal conductivity of the Test body are important mutual factors determining the thermal insulation in the test process. Therefore, the most important factors in the KS F 2278 test are the temperature and the thermal conductivity.

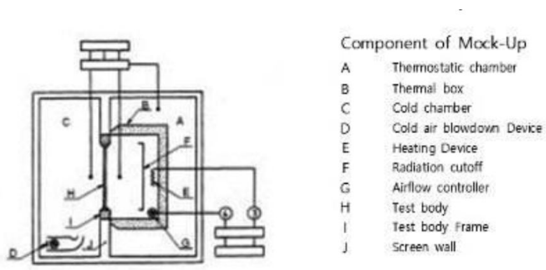

Figure 3. Component of KS F 2278 (Source: KS, 2017)

- KS F 2292 Test: This test is intended to determine the level at which air can enter the gaps between parts of the window and classify the rating for this performance. The test device consists of a box that can withstand the pressure to be injected, a test body frame to hold the test body, a pressure application device and a manometry device to measure it. The configuration of the test apparatus is shown in the figure below. Although the measured value is pressure, the performance that can actually be changed by the airtight performance is the thermal energy of the space. It can be seen from the expectation of the insulation performance of the window through the increase of airtight performance. Temperature is the most important variable in the KS F 2292 test because the ultimate goal of the performance to be expressed through the test is the increase in the adiabatic performance although the pressure is an important factor in the test itself.

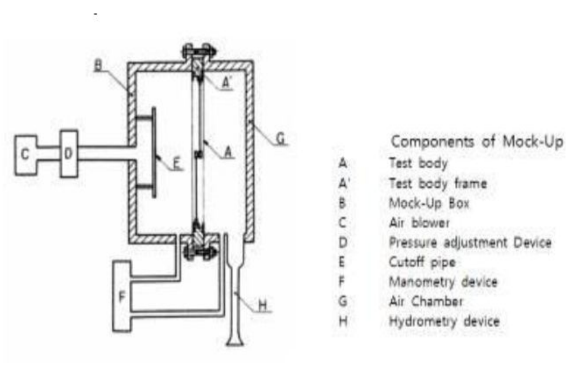

Figure 4. Component of KS F 2292 (Source: KS, 2017)

- KS F 2293 Test: This is a test to confirm the protection performance against water among the protection performance of the window. The test system consists of a test box, a water spray device and a water gauge. A unique part of this test is to visually observe the extent of leaks over time instead of specific values for leaks and to review performance.

The waterproof performance test is the important factor in the degree of joint and durability between members. Durability is a required factor due to the characteristics of the window which has both the role of having the protection performance from the external environment and the role of the opening.

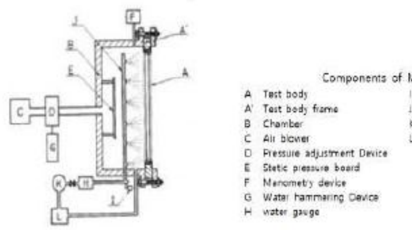

Figure 5. Component of KS F 2278 (Source: KS, 2017)

- KS F 2295 test: This test has the purpose of evaluating the level of performance and confirming the degree of prevention of condensation that can be caused by changes in temperature and humidity. The test equipment consists of a thermostatic chamber and a cold chamber which can control the temperature to 10 ~ 30 ℃, the humidity to 30 ~ 70%, the measuring instrument which can measure temperature and humidity, and the hydrometry device. The drawing of the test apparatus is as follows.

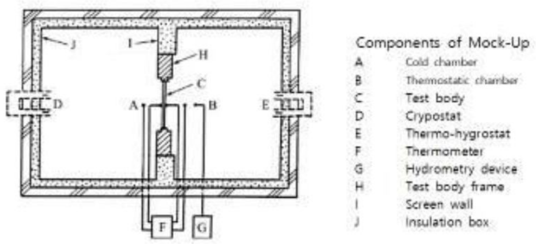

Figure 6. Component of KS F 2295 (Source: KS, 2017)

The most important cause of condensation is temperature and humidity changes. The surface temperature of the test body is proportional to the air temperature, and surface condensation appears depending on the change of the surface temperature. This phenomenon is greater when the temperature is far different between indoor and outdoor. Therefore, an important factor of this experiment is temperature, humidity, and surface temperature of test body. The performance analysis revealed four major factors influencing performance: temperature, humidity, junctions between members, and durability. KS F

2294, which tests structural performance, has not reached the level of development to be applied to current BIPV, and KS F 2296 has similarity with KS F 2292, so the two tests were excluded from the factor derivation process.

C. Analysis of Important Factors through Performance Test Analysis

Among the four factors, priorities were selected in descending order of the factors influencing the test, and the factors to be measured were classified. Priority was the most influential factor for KS F 2278, KS F 2292, and KS F 2295, and all other factors were influential factors in one test. However, in the KS F 2296 test among the exempted tests, it was concluded that the interfacial bonding was an important factor and the interfacial bonding was the second most influential factor. Therefore, the priority of the factor was classified into the order of temperature, joining between members, humidity, and durability.

D. Other Performance Tests with Important Factors

As mentioned above, transparent BIPV is still in the development stage and has not reached commercialization. Therefore, in order to test the performance of transparent BIPV, the KS test could not examined in various aspects such as specifications, performance standards, and suitability. Therefore, it is considered that it is realistic to measure the performance of transparent BIPV roughly. As a result of these conclusions, this study examined the tests that can measure important factors, focusing on field tests that can be approximated or measured in the field.

A thermo-graphic camera picture: A thermo-graphic camera is a camera that can measure the surface temperature of an object and take thermal energy or radiating energy from the surface. It is easy to carry and it is often used to measure the insulation performance in the field test because of the reliability of the photograph. It can be used for buildings built in an area or environment where there is a difference in temperature between indoor and outdoor. It is possible to confirm the approximate insulation performance by simultaneously measuring the surface temperature and indoor and/or outdoor temperature of places such as windows, walls, and balconies. Temperature is a very important factor as it is an experiment to visualize the heat, and its reliability also has a certain level of objectivity.

- Blower Door Test: This test is also used in ISO standard test. By testing the airtightness of a specific place, it is used to control the pressure in the space to find where the air leaks or to identify areas of low airtightness. The test method is to test the airtightness of the space by installing the blower door on the door after sealing the place where the air can leak. This test has an advantage that it can roughly grasp the performance of the joint of the member itself and the place where there is a gap in the space such as window, lamp, etc. in addition to the airtightness of the specific space. Figure 8 is a photograph of the blower door.

E. Examination of Condition as BIPV Performance Test

The validity of the tests was confirmed by the most important factors in the thermo-graphic camera and the blower door test. The most important factor in the thermo-graphic camera was temperature. In addition to temperature measurement, temperature visualization can be used to check insulation, condensation, and airtightness, and the measured results are used in a variety of ways, including the basis of certification schemes and citation data. The Blower Door test is also used to measure the airtightness of actual buildings. Also, it is considered that the test is reasonable because it is a confidentiality test which is used as an authentication test at ISO. Considering this, the thermo-graphic camera and the blower door test have some degree of rationality and validity in the test itself. The thermo-graphic camera and the blower door test are less reliable than the mock-up tests. Because field testing is due to the variety of factors and the different testing environments. However, if you take into consideration the above mentioned points and confirm the test results, the thermo-graphic camera and the blower door test have a certain degree of reliability and objectivity. In addition, as mentioned above, since the test is already a certain degree of rationality, the reliability of the derived value can be satisfied.

CONCLUSION

In this study, the performance index of transparent BIPV and the test to measure it are presented. Transparent BIPV and glass performance indicators are considered to be a common performance indicator among the physical performance indicators. Thus, the transparent BIPV performance indicators consist of 6 'Protecting' and 5 spatial performance indicators. As a result of analysis the KS test about the window, four important factors influence the 'Protecting' performance. Four important factors should be considered in order of temperature, bonding with member, humidity, and durability according to priority. And this study has searched each of the two tests, which were able to test important parameters, and examined whether the two tests were valid as a performance test. As a result, the thermo-graphic camera and the blower door test were found to have validity and reliability in terms of utilization. Both tests can be applied to the performance tests of transparent BIPV to be made in the future.

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