

Development of Solar Road-Block and Review for Road Application

Jae-Soon Choi[1], Yoon-Young Choi[2], Bong-Hyun Kim[3] and Sung-Ki Park[4]

[1]Associate Professor, Seokyeong University, Seokyeong-ro 124, Seongbuk-gu, Seoul, Korea
[2]Researcher, Seokyeong University, Seokyeong-ro 124, Seongbuk-gu, Seoul, Korea
[3]President, GeoTS Co., Indukwon, Geonggi-do, Korea
[4]President, CONTEC-ENG, Sungnam, Geonggi-do, Korea
Correspondence e-mail address: geotech@skuniv.ac.kr

Abstract :

First of all, we have carried out the case study of USA, Netherlands, and France where are currently conducting pilot projectson solar road. In special, to check the current status of the Solar Roadway and SolaRoad, we visited Solar Road Company and solar block plaza in Sand Point, USA. Also, we visited the bicycle road site in Amsterdam, Netherlands. In order to apply the solar panel system to the road system through literature reviews, it was considered that the development of the solar panel in the form of the road-block would be helpful for the durability during the life cycle of road.

In this study, prototypes of solar road-block were fabricated and applicability tests were conducted. The applicability tests were carried out to investigate how much electric energy could be charged from solar energy and to test the strength of acrylic panels to support the durability enhancement of solar panels. Until this year, we will examine the power generation effect of solar blocks under various conditions in actual field, and we will conduct slip resistance test and economic analysis. It is expected that the solar road will lead the future road market with the hybrid effect that plays the role of the road and energy production.

Key Words : solar panel; solar road-blockacrylic panel energh charge durability test

1. Reviews on solar roads

Currently, the United States, the Netherlands and France are the countries that conduct research on solar photovoltaic systems around the world. The Solar Roadway, developed in the United States, is a sidewalk and road that can modularly assemble solar panels. By installing LED inside the panel, it is possible to display lane by light. In addition, even in the case of winter snow, it is possible to prevent snowing and freezing by the inserted hot wire. Currently, pilot operations are planned for roads and parking lots, and there are also plans for highways. Energy generated by photovoltaic power generation in the parking lot can be consumed by itself like a streetlight. It is also expected that the provision of a charging infrastructure on the highway will help drive the road.

SolaRoad in the Netherlands tested the world's first photovoltaic bicycle road in Amsterdam in about 70m length in 2014. It is estimated that 3,000kW per hour has been developed more than expected.

The French Ministry of Environment reported a 1km extension of the photovoltaic road to a small village in Normandy at the end of 2016. The total construction cost is 6.3 billion won, and the energy generated from the pilot road was planned to be used for the operation of street lamps in nearby villages. In the next five years, theyplan to package solar panels for 1,000 km of the expressway.

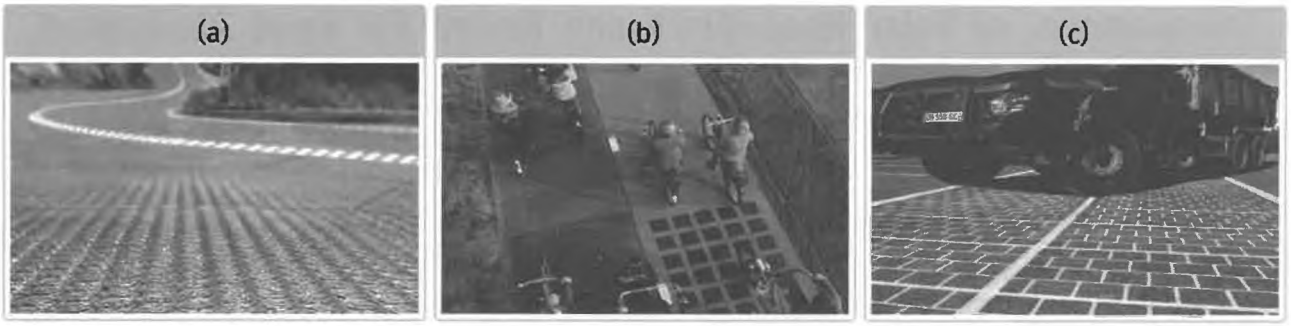


Figure 1. Solar roads (a) Solar Roadway, USA; (b) SolaRoad, Netherlands; (c) Wattway, France

2. Visit surveys

In July, 2017, we visited Solar Roadway Company in Sandpoint. In the nearby solar block plaza, control equipment was installed to check solar block and power generation in real time. Structural features were assembled by joining tempered glass to hexagonal structure. Inside, there is a power panel and an LED, and it can be seen that it emits light periodically. Because of the nature of the sunlight road, light must be transmitted through the panel surface, so glass products and acrylic products are used. Also, the surface of the panel is provided with irregularities to secure a sliding resistance. Through this visiting, we thought that Solar Roadway's products feel special as a design walkway block rather than a roadway.



Figure 2. Solar Roadway Co. in Sandpoint



Figure 3. Solar block plaza in July, 2017

In January 2018, we visited a 70m bicycle road in Amsterdam, the Netherlands. As shown in the figure, most of the panels had a lot of surface damage. However, even though it was a large panel form, severe damage such as crack was not seen. Maybe, it is because this way was only used by bikes. Also, as shown in the figure, the fact that there are the carved joints in the large panel to consider the improvement of slip resistance.



Figure 4. SolaRoad site



Figure 5. SolaRoad bike path in Jan, 2018

3. Development and verification of solar road-block

In this study, we developed a new solar block to actual road systemas shown the below figures.



Figure 6. Developed Solar panel

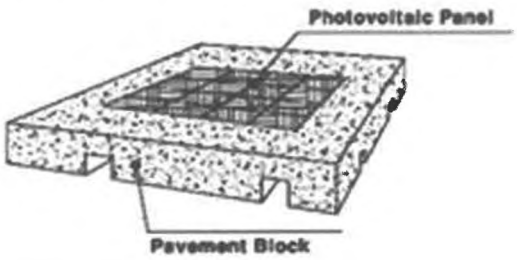


Figure 7. Developed solar road-block

For the developed solar block, 200mm of auxiliary layer thickness, which is presented in domestic road design standards, is applied equally and the surface layer thickness of 200mm, which satisfies the criteria of thickness of 80mm or more, which is the block dimension of KS F 4419, is applied. The design criteria for prototype manufacturing are shown in the following table.

Table 1. Korean design standard of block for road and developed solar road-block

Index	Unit	Standards		Apply
		Road Design	KS F 4419	
Sub-base layer (Crushed Stone)	mm	200	-	200
Thickness of Surface layer	mm	100	80	200
Block Dimensions	mm	-	300~500	300
Bending Strength Criteria (Age of 28days)	MPa	More than 4.5	More than 5.0	More than 5.0
Water/Cement Ratio	%	Less than 45	Less than 25	Less than 25

The electric power test of the solar panel to be applied to the solar block was conducted. From 9 am to 10 am, the power generation of one panel was measured to be about 2.94w per one hour. The power consumption (W) of a street lamp commonly used in Korea is 60W, and if it is used for about 11 hours per day, the power (Wh) consumed per day is 660wh. As a result, the required power generation (W) per day is calculated as 189w divided by the power consumption (Wh) per day divided by the domestic average sunshine hour (3.5 hours). By multiplying the output loss conservation factor (1.2), you can estimate the required power generation amount (W) for one street lamp, which is about 230W. For example, considering the case of a two-lane road that the road width is 6.0 m and the street light interval is 25 m, about 1667 solar block (30 cm × 30 cm) is installed. We can obtain about 4,900 W per day. Since the number of street lights within 25m intervals is 4, 920w (230W × 4ea) is necessary. So it is judged that the day power consumption of street light is satisfied. However, this is based on the assumption that the meteorological condition or the power efficiency is ideal, and it is necessary to obtain actual values of the power generation through the measurement under the field conditions.

Table 2. results of electric power test

Index	AM 09:00	AM 10:00
Solar Current(A)	0.19	0.22
Solar Voltage(V)	13.27	13.36
Solar Power(W)	2.46	2.94
Battery SOC(%)	35	53

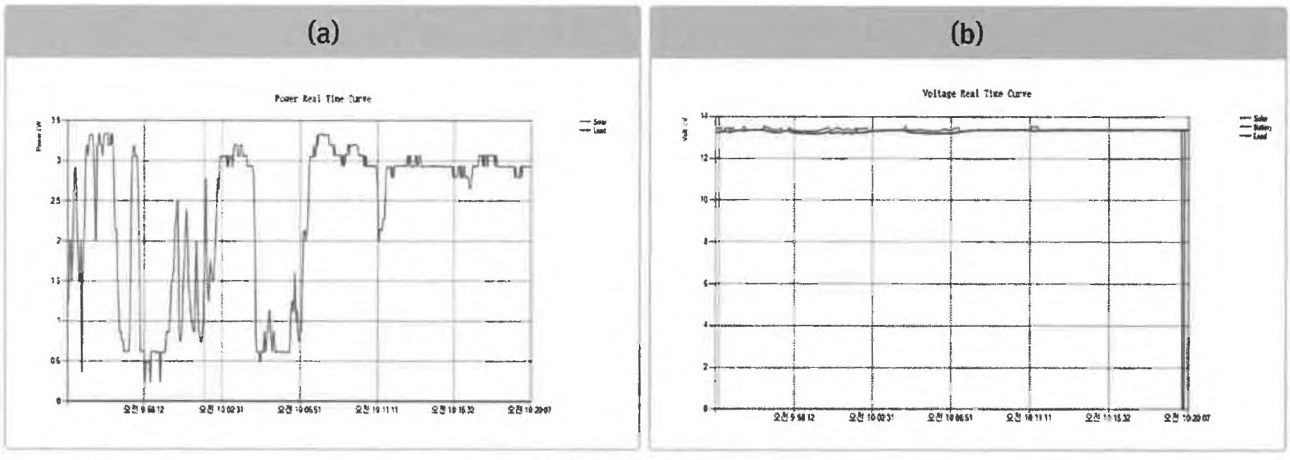


Figure 8. Electric power test of solar panel (a) Watt; (b) voltage

In this study, an experimental study on the stiffness of the solar block was also carried out. It is expected that the flexural stiffness of the block itself in the solar block using the KS standard will not be problematic for use on public roads due to the material properties of concrete. However, since the acrylic panel protecting the solar panel may be vulnerable to the load of the vehicle, the bending strength test on the acrylic panel was performed. At this time, the bending strength test was performed on the acrylic member with the thickness 20 and 25 mm. The results of bending strength tests are shown in the following figure.

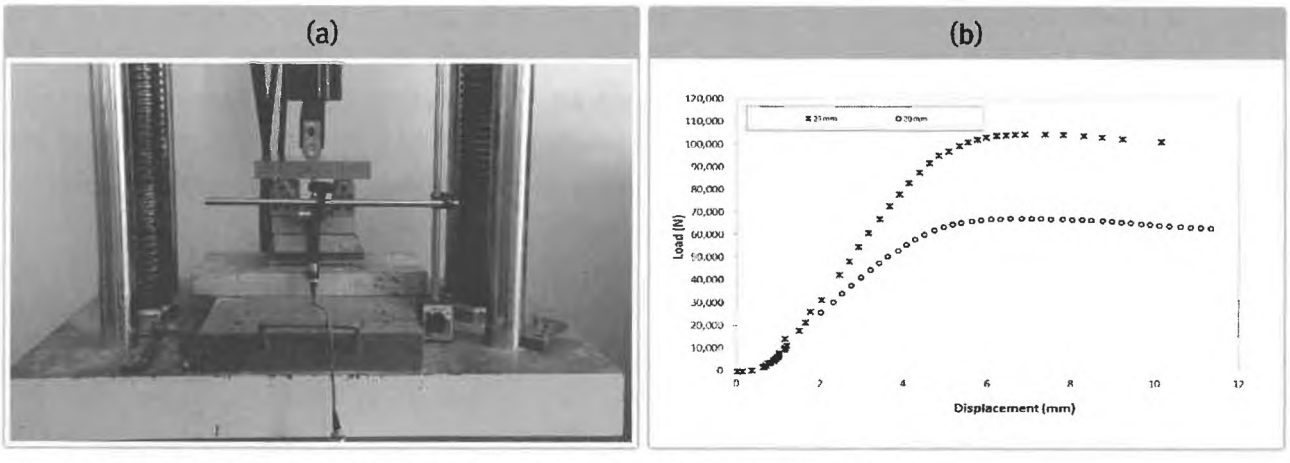
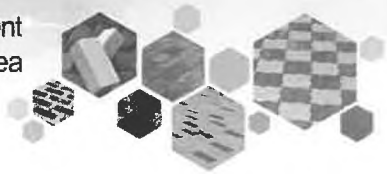


Figure 9. Bending strength test (a) test scene (b) result (P–Y relationship)



As shown in the figure 9, no failure occurredin the both cases, and the displacement occurred at the maximum load was about 6.80 mm and the bending strength was about 120 MPa. Based on the above results, the allowable stress for the vehicle load on the acrylic member was examined. At this time, considering that we apply the solar road-block in the general road and the parking lot, we adopted that the vehicle load is satisfied with the criteria of bridge grade 3. In the comparison review, the vehicle load, the criteria and final results are summarized as follows.

Table 3. Results of comparison review on the allowable stress of solar road-block

Rear wheel load 0.4W (kN)	Impact factor	Design load (kN)	Width of rear wheel (cm)	Contact width (cm)	Design stress (kPa)	Load (kN)	Stress (kPa)	Safety
54.0	1.4	75.6	50	20	0.076	1.512	0.002	O.K
			25	10	0.302	6.048	0.024	O.K

As shown in the above table, the developed solar road block is expected to be able to exhibit the allowable stress suitable for the standard of grade 3 road in Korea

4. Conclusion and future research

Through this research, we have developed solar road-blocks that can be applied in Korea through a literature reviews on solar roads starting around the world, as well as a visiting survey on overseas solar roads that have been actually tested. Until now, the solar energy under external field conditions was evaluated in time series and the optimum thickness of the acrylic panel to protect the solar panel was determined through experimental analysis. Future researches are planned to test the energy efficiency of solar road-block under various conditions in the field. Also, slip resistance of solar road-block will be tested by the wheel tracking in the laboratory.

Acknowledgements

This research was supported by a grant(18CTAP-C129740-02) from Technology Advancement Research Program(TARP) funded by Ministry of Land Infrastructure and Transport of Korean govbernment

References

[1] Choi, Jaesoon, Hwang, Choonghee, Kim, Bonghyun, Park, Sungki, Choi, Yoonyung, Problems and Solutions in Applying Solar Panel to Pavement Blocks, Korean Society of Road Engineers Conference, 2017, Korea, P25.
[2] Ministry of Land Transport and Maritime Affairs, Korean Road Design Standards, 2016.
[3] National Technology Standards Agency, Concrete interlocking blocks for roads KS F 4419, 2016.
[4] Solar Roadway Co. (USA) http://www.solarroadways.com/
[5] SolaRoad Co. (Netherlands) https://en.solaroad.nl/
[6] Wattway_Colas (Farance) http://www.wattwaybycolas.com/en/