Wind Resistance Design of Agro-photovoltaic Structure

S. Y. Lee[1], J. K. Son[1], I. H. Song[1], and K. O. Song[1*]

[1]Research Institute, KLES Inc., Daejeon, Republic of Korea

[*]Corresponding author: kiosong@kles.co.kr

1. Introduction

Recently, the Korea government is taking the policy stance for nuclear power phase-out. Moreover, the concerns about the negative effects of thermal power plants have been increasing. The situations have raised the expectations for alternative power sources and renewable energies such as photovoltaic, wind power generation, etc.

Korea has a relatively small territory, most of which are taken up for agriculture. On top of that, photovoltaic power has a low generation yield per unit area. Such limitations have made the expectations not much for the expansion of the photovoltaic power. Under the circumstances, the agro-photovoltaic has been emerging as a solution compatible between the agriculture and the photovoltaic generation. To work out such compatibility, the span between photovoltaic panels has been designed to be wider than general cases in an attempt to share the solar energy harmoniously between the agriculture and the photovoltaic. Also, to ensure passage of the farm machinery, the height of the column and the span between columns have to be higher and wider than general cases. As a result, the structure has such features that can be easily flexible and weak against the wind load.

Korea Building Code(KBC) and Korea Steel Structure Code(KSSC) is focused on relatively large and rigid structures such as an apartment, a bridge and etc. In this design practice, we have investigated suitability to apply existing regulations such as KBC and KSSC to the agro-photovoltaic structure, by using various methods such as code review, structural analysis, and wind tunnel test.

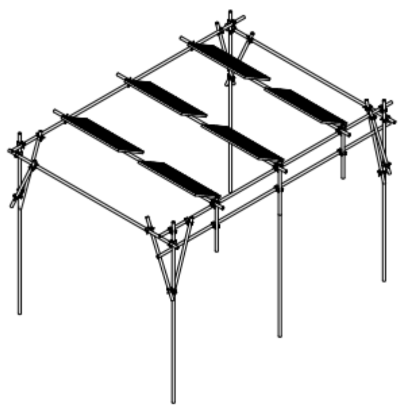

Fig. 1 General agro-photovoltaic structure

2. The code review

This review focuses on the different results between two methods for calculating wind load, which are named the general method and the simplified method, respectively. The calculations are applied to the agro-photovoltaic structure shown in Fig. 1.

The simplified method has several limitations in the application in comparison with the general method. These limitations are as follows; (1) the height must be lower than 20 m, (2) the height must be lower than the square root of multiplying the width(B) and the depth(D) (shape ratio requirement), and (3) the shape of cross-section must be symmetric and formal. Most of the agro-photovoltaic structures have satisfied these limitations. This fact can be misinterpreted as the simplified method may well be applied to the calculation of wind load on the agro-photovoltaic structure. On the other hand, applying simplified method to agro-photovoltaic structure accompanies some kinds of ambiguities such as; (1) Wind force factor in wind load calculation for the mainframe is provided only for the wall structure (whereas agro-photovoltaic structure has no wall), (2) Wind force factor in wind load calculation for the roof cannot consider gradient of the roof and an air stream under the roof.

When basic wind speed is 24 m/s and effective pressure area is 0.2 m^2, wind loads calculated by a general method and a simplified method are summarized in table 1. As shown in the table, the wind load calculated by a simplified method is smaller, by 0.4 times, than the result of a general method.

When considering ambiguities mentioned above in this section and large differences in the result of the calculation, applying a simplified method to wind load calculation for agro-photovoltaic structure has some risk.

Table 1 Comparison of wind loads calculated by the general method and simplified method

	Gust Factor	Force Factor	Enviro. Factor	Wind Load[N]
General Method	frame: 2.41	1.2	-	442
	roof: 2.17	2.1	-	525
Simplified Method	frame: -	1.1	1.5	161
	roof: -	1.4	1.5	206

3. Structural analysis

The structural analysis was conducted for general agro-photovoltaic structure (fig. 1) using the Midas gen (developed by Midas IT company). Also, the structural analysis was carried out for a matrix structure arrayed in the unit structure presented in fig. 1.

The natural frequencies obtained by structural analysis of the unit structure and the matrix structure is 2.9944 Hz and 2.2563 Hz, respectively. Such result means the stiffness of the structure decreases despite shape ratio decreases, and the second limitation of the simplified method (shape ratio requirement) is supposed to work differently from the intention of this limitation in the agro-photovoltaic structure.

Wind tunnel test

When roof structure is flexible and lightweight with the concern of aerodynamic instability, KBC has been recommending performing wind tunnel tests for the decision of wind load. Generally, the agro-photovoltaic structure is considered to have a flexible and lightweight roof. The purpose of this test is to check out the occurrence of the aerodynamic instability vibration behavior.

The geometry of the agro-photovoltaic structure used in wind tunnel test is presented shown in fig. 2. The length, the width and the height of the wind tunnel are 20 m, 8 m, and 8 m, respectively. The test object is a full-scale agro-photovoltaic structure. The applied wind speeds are 10 m/s, 15 m/s and 20 m/s.

Fig. 3, 4 and 5 show the vibration level (peak to peak displacement) during each test. This result means that the aerodynamic instability does not occur under all test conditions. The increase of vibration level during subjecting the excitation force (wind load) is important evidence for aerodynamic instability but this phenomenon has been not observed.

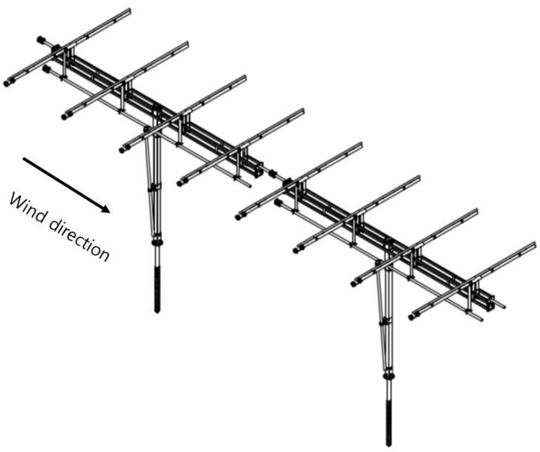

Fig. 2 Geometry of test object

4. Conclusion

Through the investigation, the following conclusions have been derived out;

- Highly recommend reconsidering the calculation method, if you had calculated wind loads for the agro-photovoltaic structure using the simplified method.
- If the wind speed considered for the agro-photovoltaic structure is below 20 m/s, you do not have to take into account the aerodynamic instability.

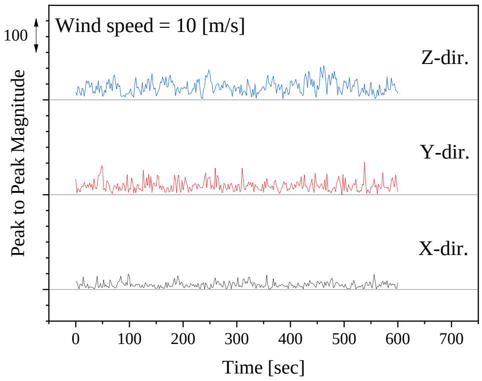

Fig. 3 Vibration level (wind speed = 10 m/s)

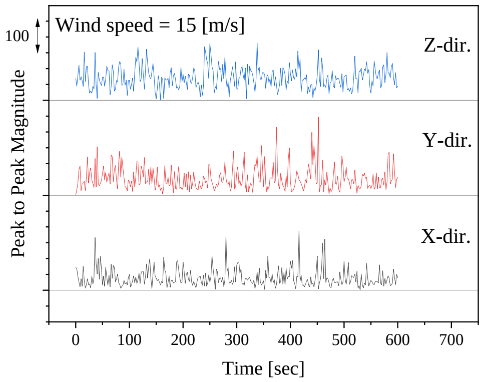

Fig. 4 Vibration level (wind speed = 15 m/s)

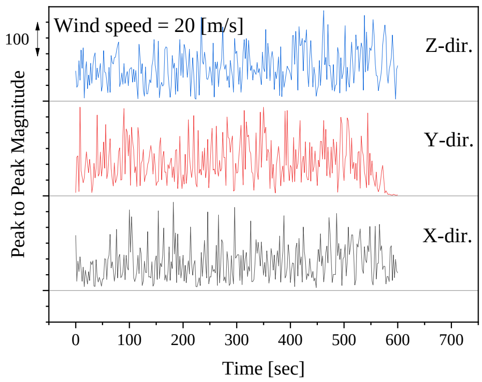

Fig. 5 Vibration level (wind speed = 20 m/s)

References

[1] KDS 41 10 15, “Korea Building Code”, 2016.