WIND LOADS ON THE ROOF-TOP MOUNTED SOLAR PANELS ARRAY WITH VARIOUS ROOF SLOPES

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ABSTRACT

A series of wind tunnel aerodynamic test were conducted to investigate the wind loads on the roof-top mounted solar panels array with four different roof slopes. In this study various location and wind angle are also to be the controlled factors. The results shown that the solar panels will be suffered the maximum wind loading at the small wind azimuth angle, especially which located on the edge region of roof. We have observed that effects of the roof slope could be a significant factor to te solar panel array wind loadings. For the wind direction is normal to the panel which located at the upstream edge and the high-end of panel toward to the approaching flow, the first row panel will be suffered serious lift wind forces. For the following panels, due to the sheltering effects their wind loadings are slightly. It is also found the sheltering effects may last up to four times of upstream panel height. For the variant roof slope the vortex shedding may change deeply by the high-rise ridge of roof, therefore the panel wind loadings will be changed. In the results of the aerodynamics tests which be conducted in this study shown the wind loadings will be rise at the high slope roof cases and the sheltering effects might be reduced in the same time.

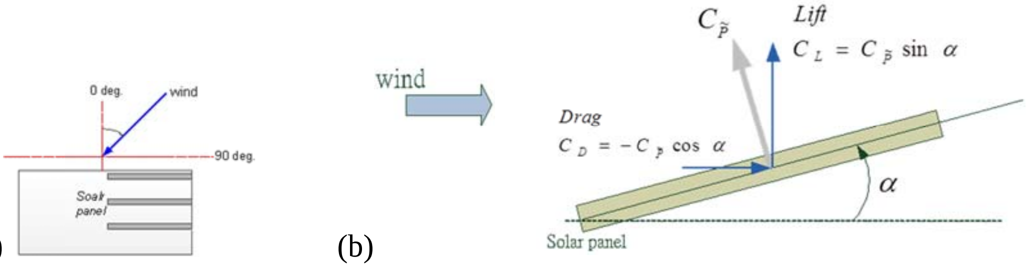
KEYWORDS: WIND LOADS, SOLAR PANELS ARRAY, WIND TUNNEL TESTS

Introduction

Using the solar panels to collect the solar energy to heat water or generate power has become very popular in Taiwan area, also in many countries. Under the extreme weather condition in Taiwan, the wind resistance ability and aerodynamic characteristics acted on them should be considered carefully. According the past study, the pressures distribution on the building roof will be affected by the separation shear layer of buildings roof edge deeply. So the location of solar panel at building roof should be selected carefully. For the efficiency reason, for many times the solar panels are installed in an array type. The wind loadings of the panels should be changed for the different row locations. And in many cases the roof types are not flat, the effects of roof slopes will also be check in this study.

Experiment Setup

A series of wind tunnel aerodynamic test were conducted to investigate the wind loads on the roof-top mounted solar panels array with four different roof slopes. The experiments were conducted at an atmospheric boundary layer wind tunnel in the Architecture and Building Research Institute of the Ministry of the Interior, Taiwan, in which the constant-area test section is 2.6 (height) × 4 (width) × 36.5 m (length). In this study the changing of wind azimuth angle is made by the controlled rotation of turn table with models set in wind tunnel test section. The definition of win azimuth angle is shown as figure 1(a).



(a) (b)

figure 1. The definition of (a)wind azimuth angle, (b)wind net pressure.

The terrain C atmospheric boundary layer flow field is adopted in this study, and geometric scale is 1:200. The acrylic made solar panel model is adopted which size is 2 cm x 30 cm. The acrylic plate made flat roof building model size is 60 cm (B) x 40 cm (D) x 20 cm(H), resulting in a blockage ratio of 0.8%. To check the effects of wind roof slope, three different slopes roofs are made for the similar rectangular size building models. The slopes of roof are included 1 to 2, 1 to 4 and 1 to 8.

Result and Discussion

Sheltering effects of panels at variant spacing

To check the affection of upstream panel, the 3 row panels array had been installed on flat roof. The results shown that the first row panel is always suffered extreme negative wind pressure. Following, the 3 row panel array with different spacing tests are conducted. Spacing between the panels is changed 2 times of panel height in each case. The following panel will be benefited by the upstream panel for the sheltering effect. In this study, the sheltering range could be up to four time of the panel height. The results also showed in the figure 2.

Spatial correlation of panel pressures

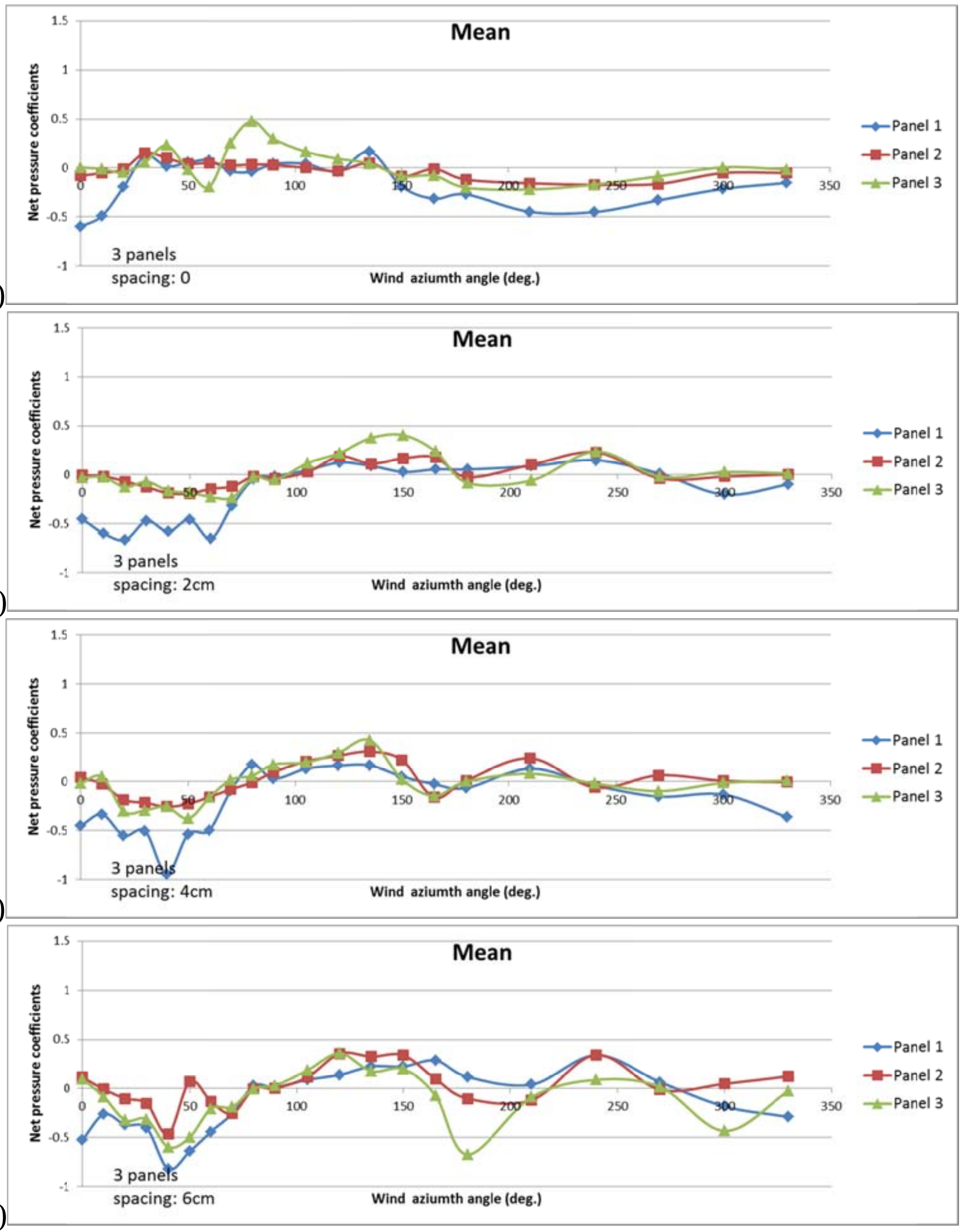
The wind pressures on the panel surface always contain high fluctuating pressures, so the spatial correlation coefficients are checked. The results shown, the pressures on panel only slightly correlated to other panels. Although the panels rows are installed with tight spacing, it seems that the separation shear layers are developed by each panels itself only. So the spatial correlation coefficients in the series experiments are small and close to zero.

Location effects to the wind loadings on panels

Since the wind pressures distributions on the roof top are complicate, wind loadings on the panels array which installed on roof top would also be changed according to the installed locations. In this study the net pressures of panels with variant distances of roof edge to the first row panel are checked. However, the serious wind loadings are always found on the first row panels and the following panels are less than them. Comparing the net pressures on first panels row with variant distance from roof upstream edge, it is found that the serious negative pressures will be released significantly for the distance larger than one tenth of building height. In this belt region around the roof edge will be not commented to install solar panel array.

The effects of roof slope to the panel wind loadings

Variant roof slope models are made to check the wind loadings on the panels, and the results of mean net pressures are showed in figure 3. Basically, the first row will suffer the strong wind loadings and the following panels are protected. On the first row panel with variant roof slope, it is evident in the figure3, the negative wind pressures effects will be enhanced for the high roof slope cases. Especially, when the high-end of solar panels are toward the approaching flow the lift forces will be rise. In the cases of variant roof slope, we can find that the negative net wind pressures will be serious at high roof slope cases. And the sheltering effect also be reduced at the roof slope over 1 to 2.



(a) (b) (c) (d)

Figure 2. The mean wind net pressures on three rows of solar panel with variant spacing in the unit of panel height, (a)no spacing, (b)2, (c) 4, (d)6.

Conclusions

A series of wind tunnel aerodynamic test were conducted to investigate the wind loads on the roof-top mounted solar panels array with four different roof slopes. The results showed, the sheltering effects are very evident among the panels. The upstream panels can provide some protection to the downstream panels up to four times of panel heights. But the spatial correlation coefficients of pressures on panels are very low, although they are installed together on the roof top. For the safety of panels, the belt region in width is one tenth of building height around roof top is not recommended for installing any solar panel array. For the effects of roof slope, it is found that the negative wind pressures effects will be enhanced for the high roof slope cases to the first row panels. Especially, when the high-end of solar panels are toward the approaching flow and the lift forces will be rise. And the sheltering effect also be reduced at the roof slope over 1 to 2.

Acknowledgement

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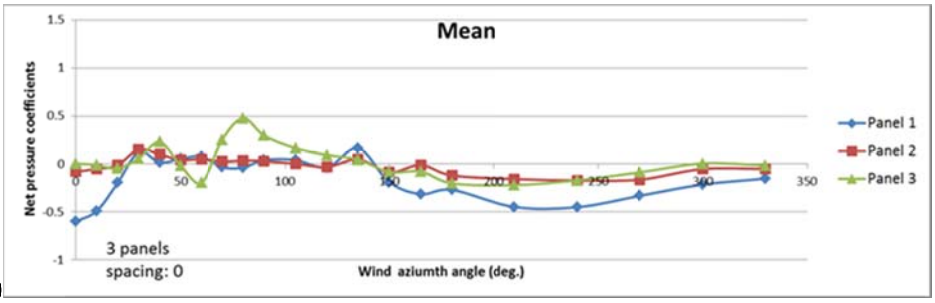

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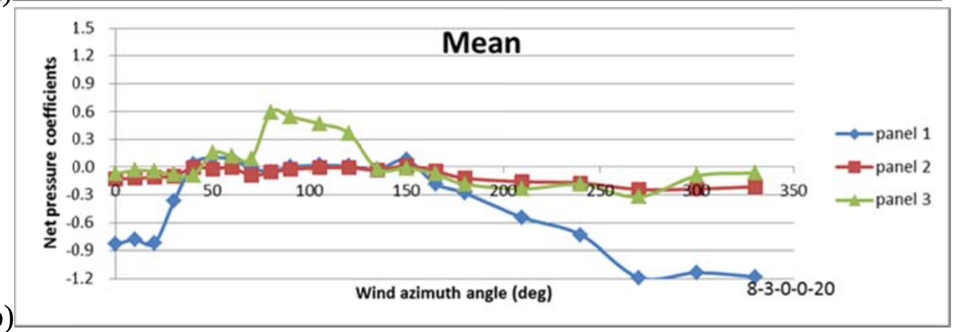

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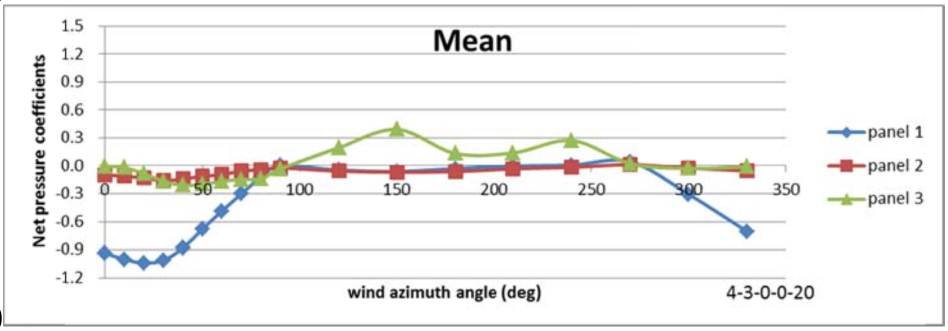

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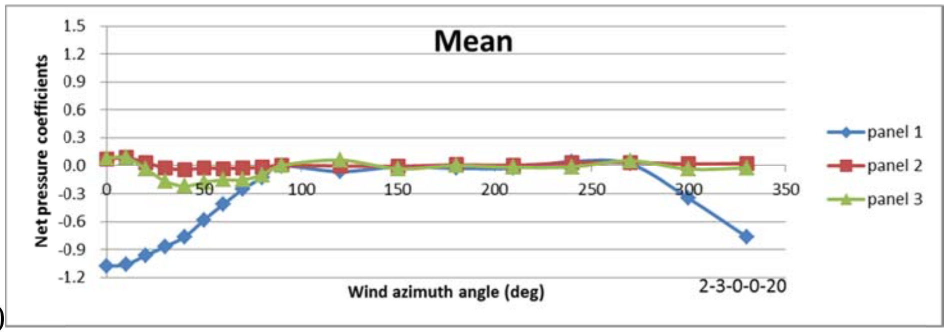

Figure 3. The mean wind net pressures on three rows of solar panels in variant roof slopes, (a)float roof, (b)roof slope 1 to 8, (c)roof slope 1 to 4, (d)roof slope 1 to 2.