Wind Engineering Joint Usage/Research Center
FY2019 Research Result Report

Research Field: Wind Hazard Mitigation
Research Year: FY2019
Research Number: 19193002
Research Theme: Aerodynamic Characteristic of Retractable Dome Roofs

Representative Researcher: Sungwon Yoon

Budget [FY2019]: 300000Yen

1. Research Aim

Since an interest has been increased in leisure, sports, etc. as the cultural level of people around the world has risen, it is in the tendency that an interest in and a demand for the spatial structure of around 200m-300m have been gradually increasing. Accordingly, demand and interest are particularly growing for the retractable spatial structure, due to its advantages of actively coping with the climate change and of the effect of energy saving. Of them, the membrane retractable dome, utilizing the light membranes and cable, has the advantages of economical driving energy, maintenance cost, and short switching time; due to the nature of using cables, it can cover a large space only with low load. However, in the case of the retractable dome, it has been found that it is vulnerable to strong winds due to its characteristic of the use of lightweight structures and materials, actually causing many damage cases. Because the retractable dome roof is operated with the roof open or closed depending on the situation, the wind loads must be considered according to each condition. However, the research on the retractable dome roof has been lacking, compared to that on a general closed dome roof. So, the characteristic of the wind pressure to the retractable dome was analyzed by the wind tunnel test in this research. Also, the applicability of the current wind load code was reviewed through the comparison between the experiment and wind load code.

2. Research Method

The retractable dome roof model used in this research is 30% (0.12m) of central open dome on the basis of diameter D and the rise of the dome roof f is 0.04m and the diameter of the model D is 0.4m. A turntable which can adjust the wall height H as 0.04~0.2m was used for the wind tunnel test (See Fig. 1). The length scale was 1/150, the velocity scale is 1/3 and the time scale was 1/50 in this test. Accordingly, actual time 10 minutes was 12 seconds in the wind tunnel. Sampling frequency was 1kHz and all pressures were measured at the same time using multi-channel pressure system. Power-law index is α=0.21 and it is corresponding to the ground surface roughness B (Urban area) based on the wind load code of Japan and Korea, and the turbulent boundary layers were realized using various spires and roughness blocks. Mean, RMS, maximum and minimum pressure coefficient have been calculated by the time series of the wind pressure coefficient. And then wind pressure characteristics were investigated through the analysis of the wind pressure coefficients, and also compared with the KBC2016 code (The code value of KBC2016 is same with AIJ-RLB(2015)).

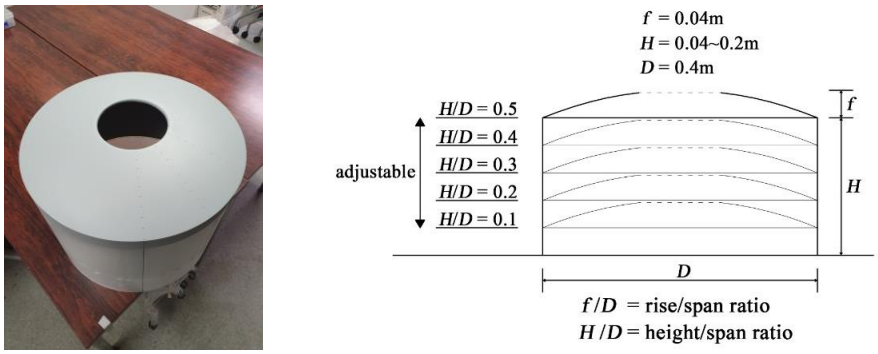
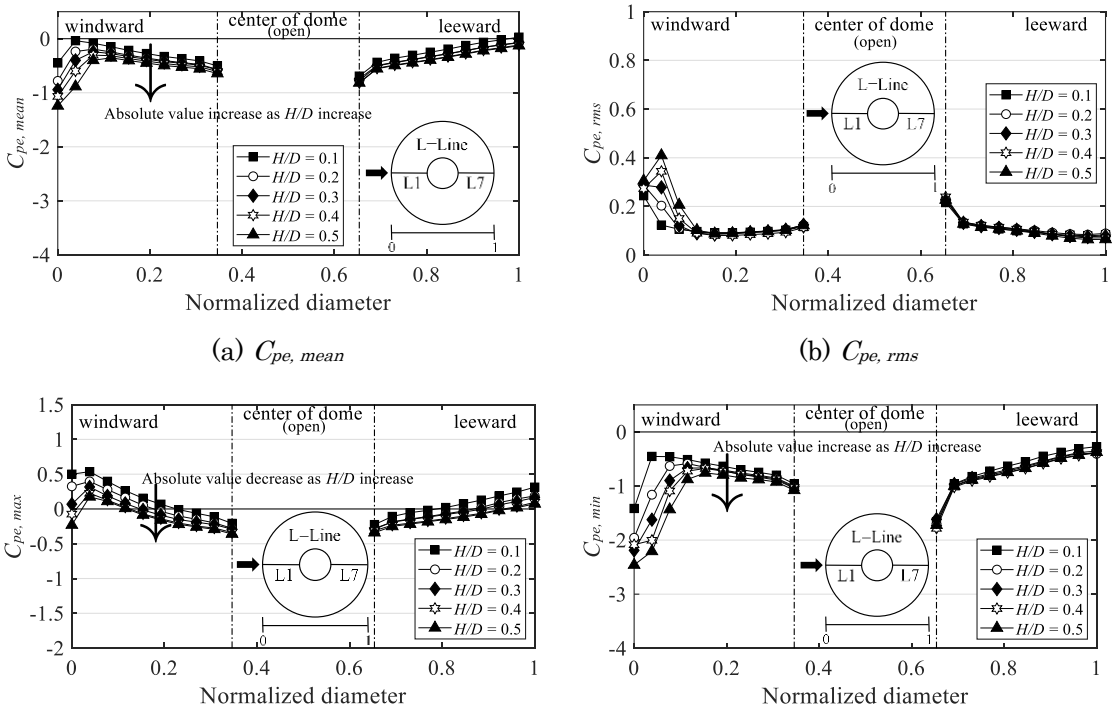


Fig. 1. Model and section

3. Research Result

Fig. 2 is the wind pressure coefficients of the central open dome. *x* axis is normalized diameter based on the distance of pressure tap installed at the roof and diameter *D*. Normalized diameter 0 is the roof edge of the windward region and 1 is the roof edge of the leeward region. *y* axis is each wind pressure coefficient. Absolute value is large due to the influence of separation in the range of about 0 to 0.2 of normalized diameter, which corresponds to the windward region, and shows a radical change. The flow at the range of about 0.2~0.38 of normalized diameter was stable. The absolute value tended to increase slightly due to the separation again at the normalized diameter of 0.64, which is the roof edge of the open area (See Fig. 2 (a), (b) and (c)). However, absolute value of $C_{pe,\,max}$ at normalized diameter of 0.64 was not changed. This is considered to be related to the boundary layer formed on the dome surface. And, the absolute values decreased at the range of about 0.7~1 of normalized diameter which is corresponding to the leeward region due to the pressure recovery.

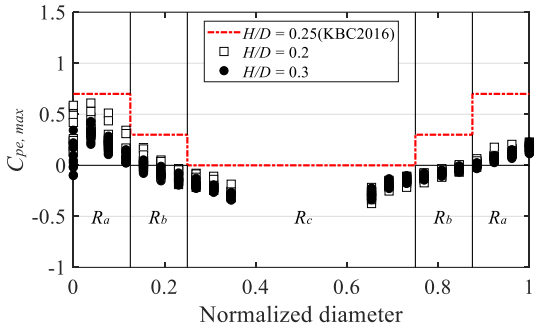


(a) $C_{pe,\,mean}$ (b) $C_{pe,\,rms}$

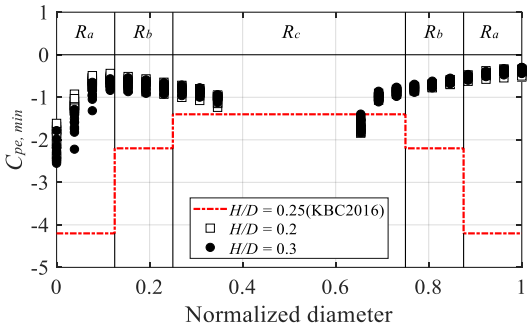
(c) $C_{pe,\,max}$ (d) $C_{pe,\,min}$

Fig. 2 Wind pressure coefficients of central open dome

Fig. 3 is the comparison between the code value and the test value of KBC2016. X axis is same with Fig. 2 and y axis shows maximum and minimum wind pressure coefficients. Also, red dot line shows the code value for each area. The maximum wind pressure coefficients did not exceed the code value at all the areas. In case of minimum wind pressure coefficients, the test values did not exceed in R_a and R_b area, but, in R_c area exceeded the code due to the influence of the separation.



(c) $C_{pe,\,max}$



(d) $C_{pe,\,min}$

Fig. 3 Comparison with KBC2016

Table 1 summarizes the peak pressure coefficient for cladding design of the central open dome roof proposed on the basis of the results of pressure coefficient analysis and code comparison. The minimum peak pressure coefficient of the R_c region exceeding the code was proposed, and this region showed a similar value regardless of H/D and turbulent intensity changes, so it was proposed as one value (-1.8) for H/D 0.1 to 0.5.

Table 1. Proposed peak pressure coefficients for cladding design of central open dome

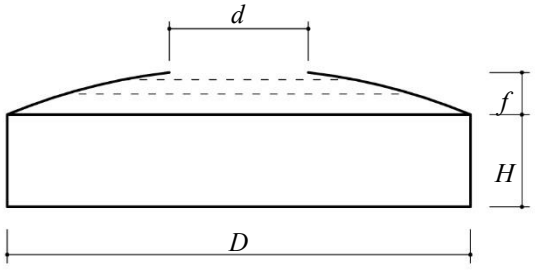
(a) Minimum peak pressure coefficients

f/D	R_a	R_b	R_c
	$H/D \leq 0.5$		
0.1	Use the value of wind load code		-1.8

(1) The area definition follows the KBC2016 code method (same as AIJ-RLB (2015)).

(2) These values are applicable only when the diameter d of the central open area is less than the following equation.

$$d \leq 0.6(D/2)$$



d : diameter of open area

H : wall height

D : diameter of dome

f : roof rise

4. Published Paper etc.

[Underline the representative researcher and collaborate researchers]
[Published papers]
1. None

[Presentations at academic societies]

1. It will be presented on October because the conference schedule of Korea Association for Spatial Structure is postponed due to the COVID-19

5. Research Group

1. Representative Researcher

Sungwon Yoon

2. Collaborate Researchers

Yongchul Kim

Jongho Lee

Dongjin Cheon

6. Abstract (half page)

Research Theme : Aerodynamic Characteristic of Retractable Dome Roofs
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The characteristic of wind pressure for central open dome roof is surveyed in this research. As a result of analyzing the pressure coefficient, the windward and leeward regions showed the same changes as the closed dome roof, but it was confirmed that separation occurred again in the center of dome region. In addition, as a result of comparison with the current wind load code (KBC2016), it was confirmed that the experimental value in the center of the dome exceeds the code value because of separation. Based on these results, the peak pressure coefficient for cladding design of central open dome roof was proposed. This result can be useful for the development of wind load code related with the cladding design of retractable dome roofs.