# Characteristics of Wind Pressure Fluctuations on Dome-like Roofs: Wind Pressure Coefficients and Power Spectra

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Dome-like Roof　Wind Pressure Fluctuation
Transfer Function　Least Square Method

## 1. Introduction

Dome-like roofs are commonly constructed among large-scale structures. Such kind of curved geometric design makes the estimation of wind loads a laborious task for wind engineers. Many researchers have investigated characteristics of wind pressure on dome-like roofs and proposed estimation methods of wind loads. However, the changing of the power spectra of wind pressure fluctuations from upstream to downstream has not been provided a clear description (Ogawa). This research intends to investigate wind pressure fluctuations on the dome-like roofs systematically. Power spectra on dome-like roofs are presented to show different patterns in different positions. Approximations based on least square method are then used to give a proper parametric description.

## 2. Experiment Setting

Wind pressure measurements are conducted in a boundary layer wind tunnel with a 12.0m (length) × 2.0m (width) × 1.8 (height) dimensions. A turbulent boundary layer flow similar to urban terrain (α=0.27) is used. Figure 1 shows the mean wind velocity and turbulent intensity profiles. Wind speed is about 10 m/sec at the boundary height, 1200mm. Pressure channels are installed parallel in the along-wind direction with the interval equals to 50mm. Figure 2 shows the arrangement of pressure channels and the combination of dome roof and cylinder acrylic models. In this research, only f/D=0.2 (naming "A"), 0.5 (naming "D") and h/D=0.0 (naming "0"), 0.2 (naming "2") are used for pressure measurements. Turbulent intensity varies from 18% to 24% and Reynolds number varies in the range of $0.91\times10^5$~$1.28\times10^5$ at model heights.

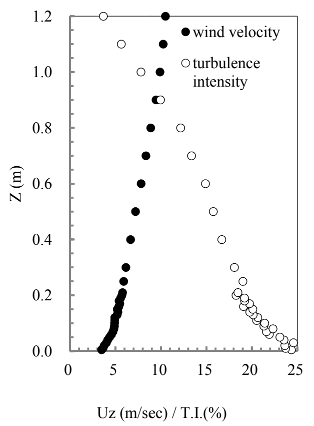


Figure 1 Profiles of turbulent flow

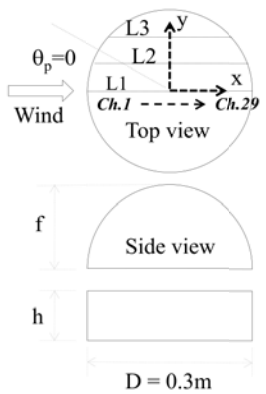


Figure 2 Geometric model diagrams

## 3. Distributions of Wind Pressure Coefficients

All dynamic pressures measured are normalized by the velocity pressure at the model heights. Figure 3 shows mean values of wind pressure coefficients. Positive values can be observed in the upstream part along L1 and L2 in all models. The distributions in models with f/D=0.2 and that with f/D=0.5 are quite different, especially in the downstream part.

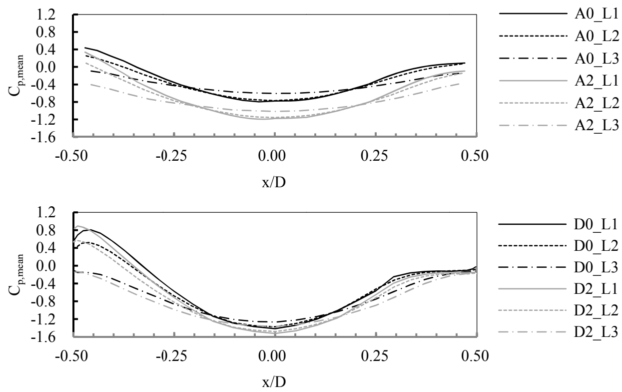


Figure 3 Mean wind pressure coefficients

Figure 4 shows R.M.S. values of wind pressure coefficients for all models. As f/D increases from 0.2 to 0.5, the variations become more scattered.

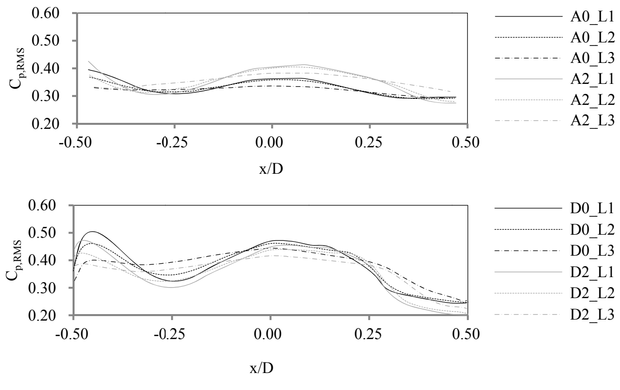


Figure 4 R.M.S. wind pressure coefficients

## 4. Characteristics of Power Spectra of Wind Pressure Fluctuations

Characteristics of power spectra of wind pressure fluctuations can be presented by transfer functions, which are defined as Equation (1). $S_{p,i}(f)$ represents the power spectrum of dynamic pressure of i-th channel on dome roofs; $S_{UH}(f)$ represents the power spectrum of velocity fluctuations at model height; ρ is the air density and $U_H$ is the mean wind speed at model height.

$$Tr(f) = \frac{S_{p,i}(f)}{\rho U_H^2 S_{U_H}(f)} \quad (1)$$

As shown in Figure 5, transfer functions of several channels along L1 in model with f/D=0.5 (Figure 2) varies from upstream to downstream. The characteristics in the upstream part are similar to that of approaching wind. For the apex and downstream part of the dome roofs, the pattern of power spectra gradually changes with the positions, which indicates the estimation of wind loads may also be different on dome roofs locally.

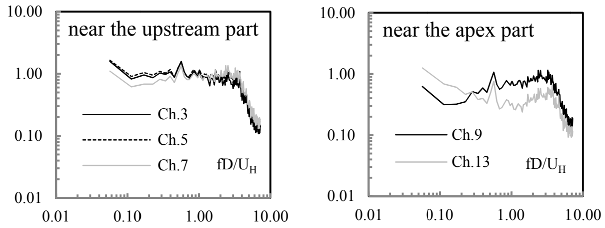


Figure 5 Transfer function along L1 in model with f/D=0.5

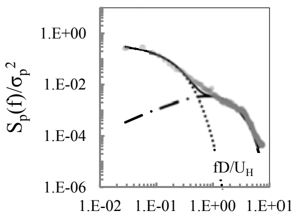


Figure 5 (Continued) Figure 6 Power spectra fitting

To give a better description of the variations of power spectra, an appropriate approximation formula is proposed. As shown in Figure 6, two exponential forms are used to fit the lower and higher frequency ranges respectively. Equation (2) shows the pure exponential form for the lower frequency range and the partly exponential form for the higher frequency range, which is modified from that proposed by Stathopoulos.

$$\frac{S_{p,i}(f)}{\sigma_{p,i}^2} = a_1 e^{-c_1 f} + a_2 f e^{-c_2 f} \quad (2)$$

Parameters of approximation forms for both ranges are fitted based on least square method separately. The envelope of two fitting curves is considered as the best approximation. However, the result should also satisfy the criteria that the integration of $S_{p,i}(f)$ equals or approaches $\sigma_{p,i}^2$. Figure 7 and 8 show two fitting parameters for the approximation of the lower frequency range. It is observed that the variations of $a_1$ and $c_1$ along L1, L2, and L3 are quite similar to each other, especially in models with f/D=0.2. The variations in the upstream and downstream part become scattered as f/D increases from 0.2 to 0.5. For models with f/D=0.2 or 0.5, L3 is slightly different from L1 and L2. However, it seems no significantly different as h/D increases from 0.0 to 0.2. Figure 9 and 10 show fitting parameters for the approximation of the higher frequency range. It is observed that the variations of $a_2$ and $c_2$ along L1, L2, and L3 gradually decrease from L1 to L3. Variations in the upstream, apex and downstream parts are so different that various patterns of power spectra should be considered when estimating wind loads for dome roofs.

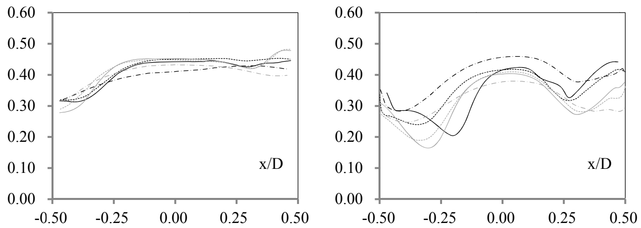


Figure 7 Parameter $a_1$ (left: f/D=0.2; right: f/D=0.5)


Figure 8 Parameter $c_1$ (left: f/D=0.2; right: f/D=0.5)

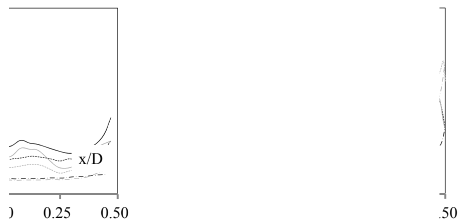


Figure 9 Parameter $a_2$ (left: f/D=0.2; right: f/D=0.5)

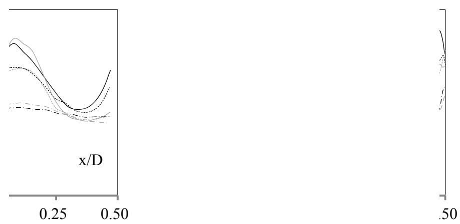


Figure 10 Parameter $c_2$ (left: f/D=0.2; right: f/D=0.5)

(Legend of each variation in Figure 7 ~ 10 is the same as that in Figure 3 and 4)

**5. Conclusions**

Distributions of wind pressure coefficients and the characteristics of power spectra are represented. It is indicated that estimation of wind loads may be significantly different with the change of positions on dome roofs.

**References**


Ogawa T. etc (1991), Characteristics of wind pressure on basic structures with curved surfaces and their response in turbulent flow, *J. Wind Eng. Ind. Aerodyn.* 38, 427-438

Stathopoulos T. etc (2001), Generation of local wind pressure coefficients for the design of low building roofs, *Wind and Structures* Vol. 4, No.6 457-468



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