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# The physical characteristics of wind pressures on low-rise buildings: Focusing on the fractal features

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**SUMMARY:**
The fractal features of the wind pressure pulse signal reflect the variation characteristics of wind pressures in time domain. Based on fractal theory, this study presents the fractal features of wind pressures on low-rise buildings under typhoon climate using the box-counting method. In fractal analysis, the fractal dimension is a quantitative parameter to assess the complexity of fluctuations and the persistence of wind pressure time series. This study investigates the characteristics of the fractal dimension of wind pressures during Typhoon Muifa(1109). The wind pressure is anti-persistent with all the fractal dimension values exceeding 1.50. Moreover, the fractal dimension values of the corner taps in the case where the mean inflow angle is close to about 45° are higher than in other cases. This study aims to enhance understanding of the physical characteristics of wind pressures on low-rise buildings during a typhoon, especially for the fractal features.

*Keywords: Fractal dimension, Wind pressure, Low-rise building*

## 1. INTRODUCTION

The wind pressure characteristics of low-rise building roofs under typhoon climate are vital to the wind-resistant design of the low-rise building. Because of the microstructure and macroscopic difference from normal winds, the typhoon can't be simulated precisely in the wind tunnels. Field measurement has become the most direct and effective technical method in the study of wind pressure characteristics. The southeast coastal region of China is tropic cyclone-prone and the most loss of life and property are caused by the destruction of low-rise buildings(Li et al., 2012).

In the past three decades, many studies have been conducted about wind effects on low-rise buildings (Caracoglia and Jones, 2009; Eaton and Mayne, 1975; Mehta et al., 1992; Wang et al., 2018). The measured results show that the high wind pressure fluctuations and peak values usually occur at roof corners for oblique winds. Moreover, earlier studies have obtained the non-gaussian characteristics of wind pressures, with the left-skewed and leptokurtic PDFs own to vortex shedding(Gioffrè et al., 2001; Xie et al., 2021).

However, the earlier studies were mainly investigating the statistical characteristics, and the analysis of the physical characteristics of wind pressure has rarely been reported. The fractal characteristics are significant physical characteristics of the wind pressure pulse signal. This paper mainly focuses on the analysis of the fractal features of the wind pressure time series, which aims to enhance the understanding of the wind pressures on low-rise building roofs.

## 2. THEORY OF FRACTAL ANALYSIS AND MEASURED DATA

### 2.1. Theory of Fractal Analysis

The theory of fractal analysis based on chaos theory was proposed by Mandelbrot(Mandelbrot and Wheeler, 1983). The fractal dimension can be used to assess the complexity of fluctuations and the persistence of time series. There are three types of time series according to fractal dimension values:

**Table 1.** Types of time series according to fractal dimension values

| Fractal dimension (D) | Types of time series |
|---|---|
| 1.0-1.5 | persistent time series |
| 1.5-2.0 | anti-persistent time series |
| 1.5 | a random process |

The box-counting method is adopted here because formulas contained in this method are easy to be converted into code on the computer processing platform for processing large amounts of wind pressure data. Details of the box-counting method have been described by Cui et al. (2022).

### 2.2. Measured Data During Typhoon Muifa(1109)

Typhoon Muifa (No. 1109) landed on the east coast of Zhejiang Province in China on August 6, 2011 and brushed Shanghai. The wind pressure data on the roof of a low-rise building were collected during Typhoon Muifa and the building is on the east coast of Shanghai. The full-scale field laboratory has a plane size of 10 m × 6 m and a height of 8 m and was located at 31°11′46″ N and 121°47′08″ E. As shown in Fig. 1, 94 measured points were assembled on the surface of the roof and some taps mentioned in the case study section are marked as black dots.

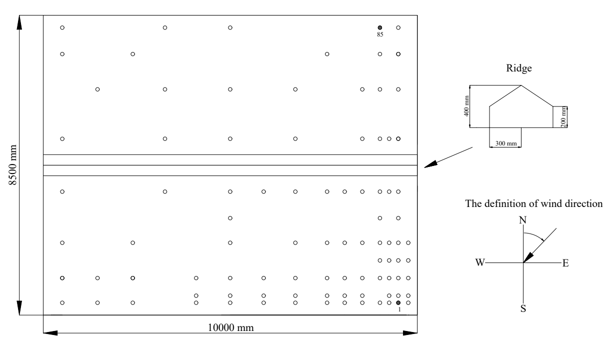


**Fig. 1.** The pressure measurement system and the definition of wind direction

The sample duration and sampling frequency for wind pressure were taken as 10 min and 20 Hz, respectively. The pressure coefficients were defined as

$$C_P = \frac{P - P_0}{0.5 \rho U_{ref}^2} \tag{1}$$

Where $P$ is the pressure of tap, $P_0$ is the static reference pressure, $\rho$ is the air mass density and $U_{ref}$ is the reference wind velocity which was measured at the altitude of 10 m from the anemometer tower.

## 3. CASE STUDY

Two cases of 10 min wind pressure data of typical wind direction were selected for fractal analysis. The case under 1.7 ° wind direction (close to 0 °) condition is determined as case A, and the case under 42.5 ° wind direction angle (close to 45 °) condition is determined as case B. The parameters of each case are listed in Table 2. The measured wind pressure time series of tap 85 at selected cases and the fractal dimension values are depicted in Fig. 2.

**Table 2.** Summary of measured cases during Typhoon Muifa

| Test Case | Roof Pitch (°) | 10-min mean wind speed (m/s) | 10-min mean inflow angle (°) |
|---|---|---|---|
| Case A | 25 | 14.70 | 1.7 |
| Case B | 25 | 14.29 | 42.5 |

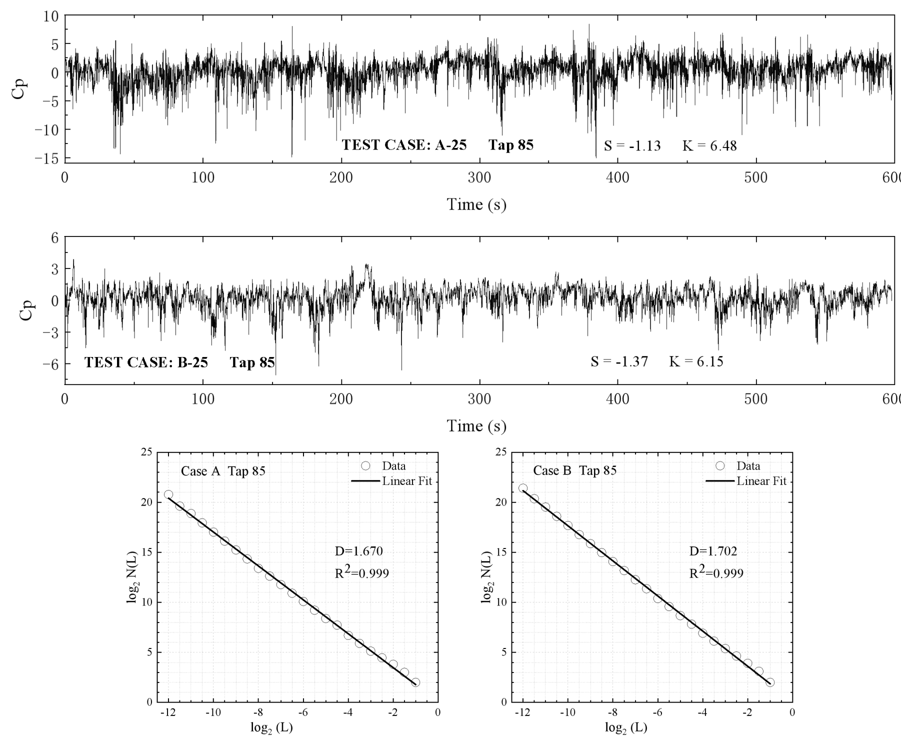


**Fig. 2.** Measured wind pressure of tap 85 at selected cases and the fractal dimension values

## 4. CONCLUDING REMARKS

In this study, the fractal features of wind pressure pulse signal were obtained using the data from field measurements. In this paper, records of wind pressure data in the roof of a low-rise building were divided into 10-min segments for fractal analysis and typical cases were selected. The main findings can be summarized as follows:

(1) Fractal behavior exists in the wind pressure time series under typhoon climate.

(2) The wind pressure is anti-persistent with all the fractal dimension values exceeding 1.50 for each 10-min segment.

(3) The fractal dimension values of the corner taps in the case where the mean inflow angle is close to 45° are higher than in other cases.

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