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THE INTERFERENCE EFFECT OF SURROUNDING BUILDINGS ON WIND LOADS OF LOW-RISE BUILDINGS

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Abstract: *Systematic experiments were conducted in a wind tunnel in order to find the effect of typical building arrangements on the wind-induced pressures, the primary goal is to better understand and quantify the effect of surrounding buildings on wind loads on low-rise buildings. The parameters related to low-rise buildings with flat roofs include relative height, area density and arrangement of surrounding buildings. Based on these results, more comprehensive conclusions should be made which will lead to some recommendations for wind standards or building design.*

Keywords: interference effect, surrounding buildings, wind load, low-rise building.

1 INTRODUCTION

In general, low-rise buildings are usually surrounded by surrounding houses, and wind loads on low-rise buildings are definitely affected by these neighboring houses. Previous results show that wind loads in a realistic environment do not always follow the basic wind load characteristics of an isolated building because of interference by neighboring buildings. Ho et al. [1] investigated low-rise flat roofed buildings, embedded in a typical North-American industrial area. Surry [2] examined the effect of both surroundings and roof corner geometric modifications on the roof pressures measured on a low-rise building. Kiefer and Plate [3] provided modeling of mean and fluctuation wind loads in different types of build-up areas. Chang and Meroney [4] investigate the effect of surroundings with different separation distances, and compared the results of wind-tunnel measurements with that of numerical simulations.

Up to now, there exists little information on the effect of the surrounding on the wind loads. And the current wind load design codes usually just consider the effect of roughness of the upwind terrain but neglects the direct effect of neighboring houses. Yet the presence of nearby buildings is expected to deflect streamlines, modify local circulation patterns and induce modified patterns of suction and stagnation pressure. Systematic experiments were conducted in a wind tunnel in order to find the effect of typical building arrangements on the wind-induced pressures, the primary goal is to better understand and quantify the effect of surrounding buildings on wind loads on low-rise buildings. The parameters related to low-rise buildings with flat roofs include relative height, area density and arrangement of surrounding buildings. Based on these results, more comprehensive conclusions should be made which will lead to some recommendations for wind standards or building design.

2 WIND TUNNEL TEST

Pressure measurement wind tunnel tests on low-rise buildings were executed in the Boundary Layer Wind Tunnel, in the Tokyo Polytechnic University, Japan. The length scale was set at 1/100□ the velocity scale was assumed at 1/3. The suburban terrain corresponding to terrain category III in AIJ (2004) was chose as the tested wind field. The wind velocity profile and turbulence intensity profile of the simulated wind field are shown in Fig. (1).

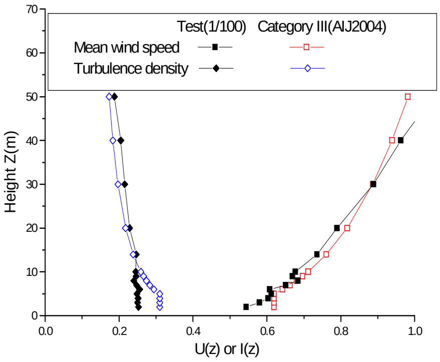


Figure 1: The 1/100 simulated suburban wind field

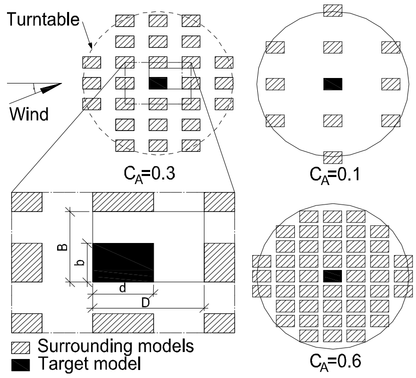


Figure 2: Definition of C_A

The flat-roofed low-rise building models for test have same plan size of 24cm length and 16cm width, and three model heights (H), 6cm, 12cm and 18cm. In wind tunnel, A large number of 'dummy' models of similar dimensions were constructed to represent surrounding buildings, and area density C_A was defined as,

$$C_A = \frac{area\ occupied\ by\ buildings}{area\ of\ \ site} = \frac{bd}{BD} \tag{1}$$

where, b and d are the breadth and depth of the buildings. B and D are the average distances between corresponding points on adjacent buildings in two coordinate directions, as shown in Fig. (2). The target model is set at the center of a turnable of 200cm, surrounded buildings are arranged in 3 kinds of orders (i.e. regular, staggered, random), as shown in Fig. (3), with 8 different area density C_A (0.1, 0.15, 0.20, 0.25, 0.30, 0.40, 0.50 0.60), and the heights of surrounding building models (H_s) are also varied in 60, 120, 180cm. Each of the experimental models is set on the turntable in isolation settings which are called isolation test cases. The test results of the isolation test cases are referred to as the standard values.

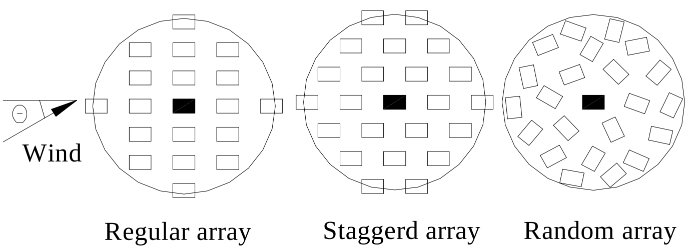


Figure 3: Arrangement Order of surrounding buildings (C_A=0.25)

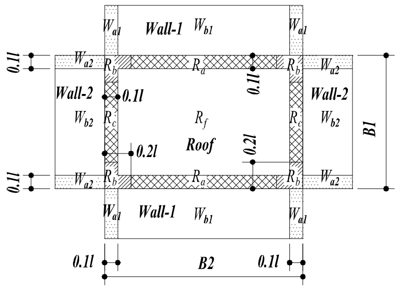


Figure 4: Zone definition

In this test, the sampling frequency was 781.25Hz and the sampling period was 18 seconds for each sample, corresponding to 23.4Hz and 10 minutes in full scale. Each test case was sampled 10 times. The test data were then low-pass filtered at 300Hz.

In order to quantify the effect of surrounding buildings to the wind loads of target building, the interference factor, C_I, which represents the change of statistical pressure coefficients caused, is expressed as:

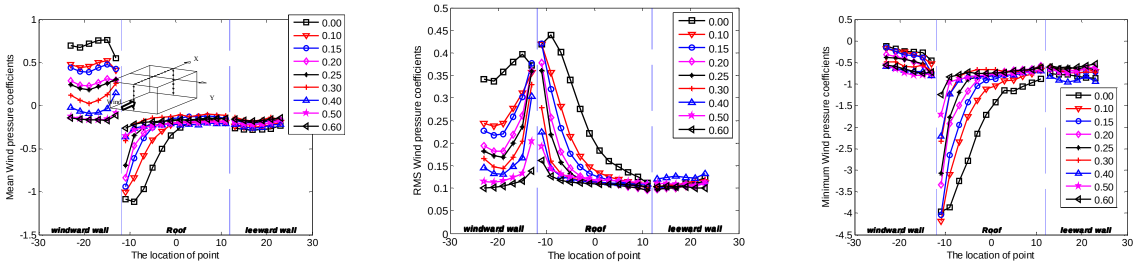
$$C_I = C_{p,sur} / C_{p,iso} \tag{2}$$

where, $C_{p,sur}$ and $C_{p,iso}$ are the local extreme pressure coefficients over all wind directions measured under the experimental model surrounded by neighboring houses and under the isolated test case, respectively. Furthermore, the area-average values of C_I for building surface zones defined by AIJ2004 shown in Fig. (4) are calculated as well, where the whole surface Roof, Wall-1 and Wall-2 is denoted for the positive extreme cases.

3 RESULTS AND DISCUSSION

3.1 The effect of area density of surrounding buildings

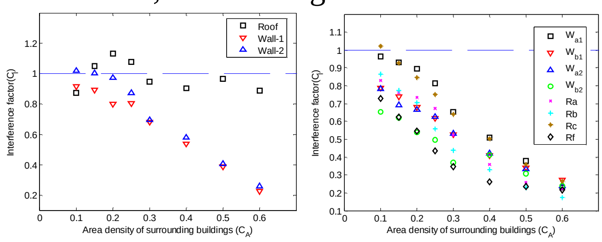
High suction pressures over the building surface are significantly reduced for a building surrounded by other buildings compared to the isolated building in the same approach flow, in terms of the peak, mean or root mean square (RMS) Cp. All three statistical interpretations of pressure variation are significantly reduced by the presence of surrounding buildings. See Fig. (5) for detailed Cp comparisons on a single building and all surrounding cases depending on the different C_A, where 0.0 means isolated case.



(a) Mean wind pressure (b) RMS wind pressure (c) Minimum wind pressure

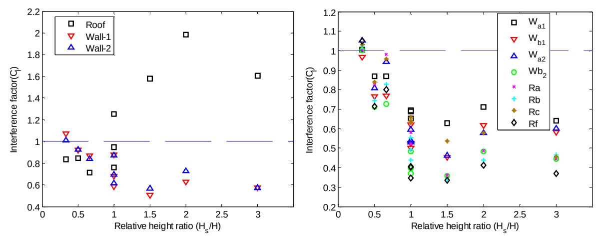
Figure 5: Pressure coefficients (peak, mean and RMS) on the centerline of building under different C_A at the azimuth of 0, H=12cm, H_S=12cm, in regular arrange order

As the density of surrounding buildings increases, the average peak negative wind pressure coefficients on most of the zones decreases, especially for the average peak negative wind pressure coefficients in regular order, as shown in Fig.(6). At the case of relative height ratio of H_S/H=1, the peak positive wind pressure coefficients of roof are increased nearly 20% with the increase of the density of surrounding buildings in sparse density cases (C_A <0.2), but for other zones, there are significant decrease with the increase of C_A.



(a) Maximum (b) Minimum

Figure 6: Interference factors for peak wind pressures under different area density cases, H=12cm, H_S=12cm



(a) Maximum (b) Minimum

Figure 7: Interference factors for peak wind pressures with different relative height ratio, C_A=0.1, 0.3, 0.6

3.2 The effect of relative height ratio of surrounding buildings to target building

As noted previously, the different building height configurations are considered. Depending on the relative height ratio (the ratio of height of surrounding buildings to that of target building, H_S/H), there is significant increase of peak positive wind pressure coefficients with the relative ratio on roof areas in regular order, as shown in Fig.(7). The peak negative wind pressure coefficients under lower relative height ratio (H_S/H<1.0) are usually higher than that of bigger relative height ratios (H_S/H<1.0).

3.3 The effect of arrange order of surrounding buildings

In particular, the present study would like to detail the relationship between arrangement (e.g. regular, staggered, or random) and the level of interference which results. However, due to the scatter of the results, it would be difficult to lead to some clear conclusions, which also indicate that the effect of area density and relation height ratio are much sensitive than the effect of arrangement of surrounding buildings, therefore the different arrange orders become secondary in comparison.

4 CONCLUSIONS

Shelter effects produced by the surrounding buildings on the central building were found to be significant, such that flow patterns are displaced and mean and peak induced loads are significantly different from the isolated building base case. It is expected that shielding effects depend on the area density (C_A) and the relative height ratio (H_S/H). The suction on the building surfaces can be significantly reduced by the presence of surrounding buildings and will be obviously decrease with the increase of C_A, but the positive peak wind pressure will increase in some cases. The environment with similar-sized buildings can lower the ambient pressure for a region below the general building height. Compared to a single building case, surrounding building arrangements can even reduce the magnitude values of mean, RMS and peak Cp's over 60%. It should be noted that the inference effect can not be attributed all to the surrounding buildings due to there is still not clear definition of the boundary layer and the additional roughness cased by surrounding buildings which is still under further research.

ACKNOWLEDGEMENTS

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