August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering
ICWE 16

Wind pressure on a building located in high-rise building cluster - Broad region LES for actual building model -

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SUMMARY:
This study estimates wind pressure on a building located in high-rise building cluster by broad region LES for actual building model. The computational domain of this study reproduces the buildings and topography within a radius of 1.2 km from the target site in central Tokyo, which is much broader than the region in ordinary wind pressure estimation. The turbulent and pressure field for target area including many high-rise buildings are computed by LES using building cube method (BCM). First, effect of velocity deficit which are induced by buildings more than 500m upwind are examined and the result shows that turbulence intensity remains up to about 800m downstream. Then, the unsteady characteristics of flow pattern which is induced by vortex shedding from windward buildings are shown, the effect on unsteady change of wind pressure on target building is examined. The results imply that turbulent field with intermittent switching in windward area of target building causes intermittent peak pressure on target building.

Keywords: Large Eddy Simulation, High-rise building, Turbulent field, Peak pressure

1. INTRODUCTION

In recent years, huge typhoons have frequently hit large cities in Japan, causing serious damage to buildings and structures. Damage to exterior claddings of building is mainly caused by wind pressure acting locally and unsteadily on building components. The local and unsteady wind pressure is influenced by a combination of turbulent structures with several scales in urban area. The unsteady changes of pressure are induced by not only turbulent structures around in the facades of individual buildings with a scale of several tens of centimeters but also large-scale turbulent structures (a scale of several hundred meters) in urban boundary layer.

In ordinary wind pressure estimation using CFD and experiments, the geometry of surrounding buildings and terrain is reproduced within a radius of about 300-400 m from the target building. However, recent advances in HPC technology have made it possible to reproduce a wider range of geometry. In central Tokyo, many high-rise buildings are scattered around the city, which are expected to show different characteristics of the approaching flow from the usual turbulent boundary layer. The previous research (Tamura et al. 2017) shows that the influence of wake turbulence from buildings on the upwind side remains 1 km downwind, which corresponds to 10 times the height of the building.

This study estimates wind pressure on a building located in high-rise building cluster by broad region LES for actual building model and reveals effect of turbulent field around high-rise building cluster on wind pressure.

2. CALCULATION METHOD AND CONDITION

In this study, the effects of wake turbulence from several buildings located more than 500m away from the target building are examined by LES using building cube method(CUBE). Simulation code is CUBE developed by RIKEN (Jansson et al., 2018). The computational domain reproduces the buildings and topography within a radius of 1.2 km from the target site in central Tokyo (Fig. 1). The height of the target building is approximately 330 m, and there are scattered high-rise buildings over 150 m around the target building. The minimum spatial resolution is 1.37 m and the total number of meshes is 400 million. For the inflow condition, wind direction of NNW is assumed as the wind direction that is most likely to be affected by high-rise buildings on the windward side, and the turbulent boundary layer which are generated by driver region simulation with the quasi-periodic boundary condition (Nozawa et al., 2002) is connected. The calculation conditions are shown in Table 1.

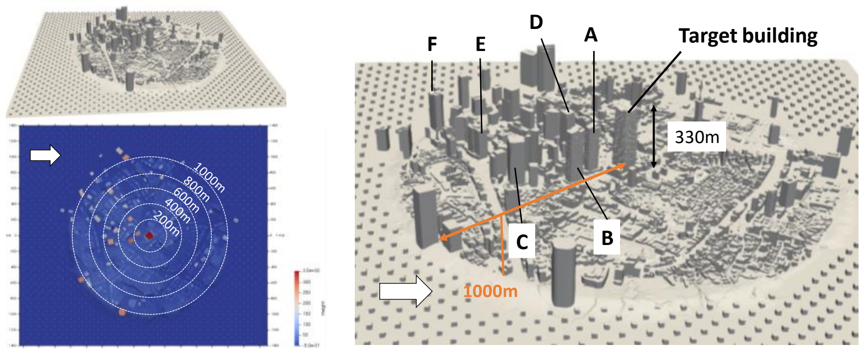


Figure 1. Target site

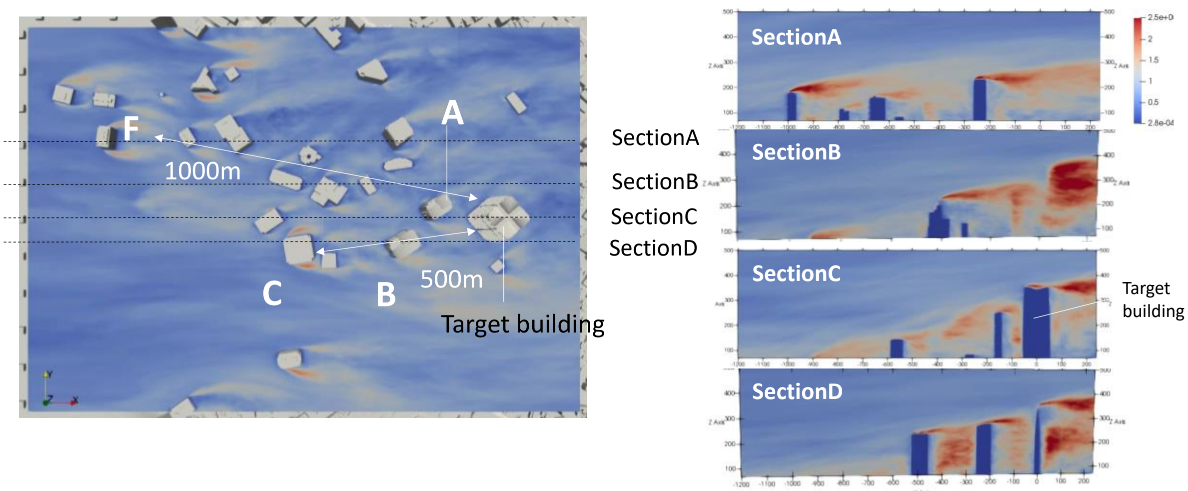
Table 1. Calculation condition

Re	65000
Resolution	Δt=0.025[s], **1.37[m]** （Minimum）
Time integration	2nd order Crank-Nicolson
Spatial discretization	Convective term:2nd order Central+5% Upwind Diffusion term：2nd order Central
Boundary condition	Wall：No-slip type IBM Side,Top：Slip Inlet：Inflow turbulence Outflow：convective

3. EFFECT OF TURBULENT STRUCTURE ON WIND PRESSURE IN A LARGE URBAN AREA

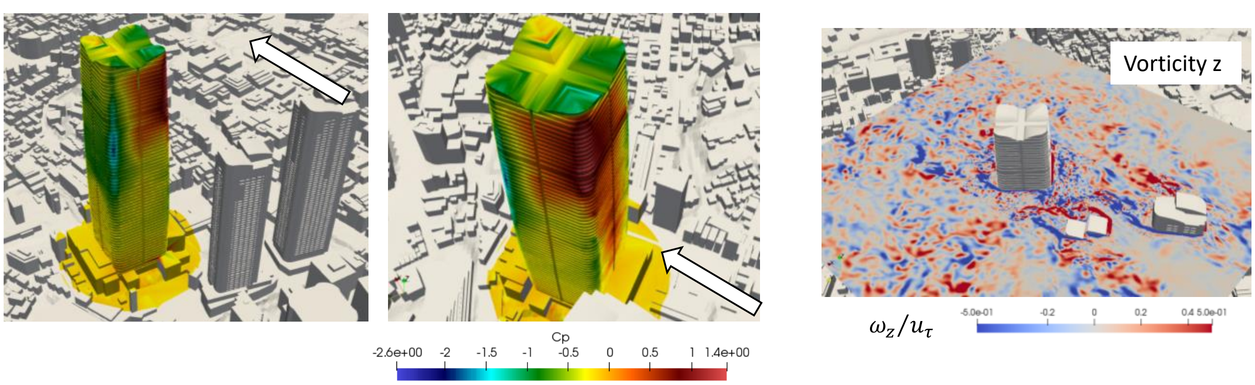
First, in order to show the influence of several high-rise buildings located in the windward side on wind pressure of target building, the distribution of turbulence intensity around the target buildings is shown in Figure 2. In SectionA of fig.2, the influence of the shear layer generated from the top of Building F appears until 800 m downstream. In Section D, the influence of buildings B and C appears clearly, and the turbulent intensity σ_u is greater than 1.5 in the area from ground to 200 m height.

Figure 3 shows wind pressure coefficient distribution (instantaneous value) on building surface and vorticity z distribution (height :220 m). Separation shear layer generated from the roof of Building A approaches to the subject building and a large negative pressure occurs at rounded corner of building. This large negative structure appears vertically at the height from 100m to 250m.



(a) Horizontal plane of turbulent intensity σ_u(Height:220m) (b) Vertical plane of turbulent intensity σ_u

Figure 2. Spatial distribution of σ_u



(a)Cp distribution on target building (instantaeneous value) (b)Vorticity z at z=220m

Figure 3. Time series of Cp on target building facade

Finally, this study focuses on the unsteady change of wind pressure Cp on target building. Fig. 4 shows the time series variations at four locations where the absolute value of Cp is large. As shown in the distribution of instantaneous wind speed and vorticity z in Fig. 4, Vortex shedding which are generated from the side corners of forested high-rise buildings interferes each other in the upwind area of the target building, and the turbulent field approaches the target building with intermittent switching. As a result, intermittent peak wind pressure is suggested on target building.

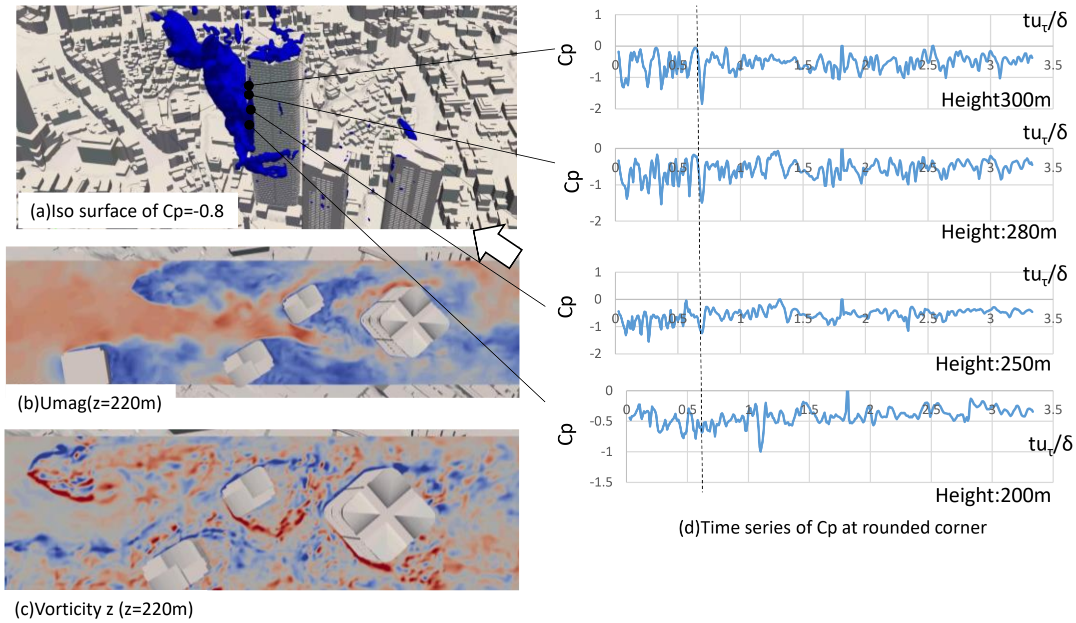


Figure 4. Time series of Cp on target building facade

4. CONCLUSIONS

LES for actual building model was carried out for a broad region of urban area including several high-rise buildings and wind pressure on target area was shown. As a result, velocity deficit and large turbulence intensity which are induced by buildings more than 500m upwind are maintained up to about 800m downstream. Then, vortex shedding which are generated from the side corners of forested high-rise buildings interfere each other in the upwind area of the target building. Finally, in the target building, large negative pressure occurs in the rounded corner, it implies that turbulent field with intermittent switching causes intermittent peak pressure on target building.

In the future, the turbulence structure associated with the fluctuations in the windward building will be extracted based on POD (Proper Orthogonal Decomposition) and the effects of vortex shedding generated from the several high-rise building and longitudinal vortices generated from the top of the building will be examined.

ACKNOWLEDGEMENTS
This research used computational resources of the Fugaku computer provided by the RIKEN through the HPCI System Research project (Project ID: hp210158, hp210262).

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