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LES Analysis of Ventilation Performance and Wind Gust Occurrence for Strategic Urban Transformation

Masaharu Kawaguchi[1*], Tetsuro Tamura[2]

[1] Tokyo Institute of Technology, Ookayama 2-12-1, Meguro, Tokyo, Japan,
kawaguchi.m.ag@m.titech.ac.jp
[2] Tokyo Institute of Technology, Ookayama 2-12-1, Meguro, Tokyo, Japan,
tamura.t.ab@m.titech.ac.jp

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There is an urgent need for ventilation improvement in urban areas in order to mitigate the risk of illnesses due to unexpected contagious viruses or airborne pollutants and improve the thermal environment in terms of heat stress reduction on individuals and achievement of a carbon-neutral society. These needs and the transformation of people's lifestyles will most likely bring a gradual or metabolic transformation of urban areas. Thus, it is important to investigate the performance of potential modifying strategies for existing urban space configuration. In the course of the evaluation, the safety in extreme weather events such as increasing landfalls of violent tropical cyclones needs to be carefully assessed at the same time. In this study, we evaluated near-ground ventilation performance improvement in an actual densely built-up urban area of Shibuya district in Tokyo, Japan, in various assumed changes in urban space configuration using large eddy simulation (LES) at the grid resolution of about 90 cm.

Firstly, we examined the average nature of the ventilation improvement in the traditional urban redevelopment model, comparing the current urban configuration and the future configuration where many mid and low-rise buildings are replaced with fewer high-rise buildings. The average flow rate near the ground (at approximately 10 m height) increased by about 20% as a result of the space reservation and wind induction to the streets by the high-rise buildings aligned in the wind direction. However, the maximum instantaneous wind speed also increased in those spaces, and thus, appropriate measures needs to be taken against the wind force damage. Also, the buildings located close to each other in the orthogonal to the the flow direction caused infavorable consequence in the downstream region such as significantly lowered ventilation and more intensified wind gusts.

To seek potential future urban transformation strategies, we performed an investigation on the local flow change around a triangle-shaped urban block composed of mid and low-rise buildings in the city center considering two redevelopment scenarios: the block is replaced with (i) one high-rise slender triangular prism surrounded by an open space and (ii) one mid-high wide triangular prism with a courtyard. Inflow turbulence for this simulation was generated using the meteorological model/engineering LES hybrid approach proposd by Kawaguchi and Tamura et al. (2019) [1], replicating the actual meteorological structure of Typhoon Hagibis (2018). Both cases created more organized flow patterns inside the canopy region and seemed to have better ventilation performance than the present case where the buildings with inhomogenuous heights and shapes in the block generate random small eddies. Concerning the wind resilience design, highly unsteady gusts were generated mainly around the building associated with vortex shedding in Scenario (i), while mean wind speed and gust levels increased along the leeward street in Scinario (ii). We are planning to quantitatively analyze more variations of building shapes and layouts regarding their effect on urban ventilation.

REFERENCES

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