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Modeling of one-cell tornado vortex and aerodynamic forces on tall building

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ABSTRACT

Tornadoes are the most devastating meteorological natural hazards and are generally defined as violently rotating columns of air, pendant from the base of a convective cloud and often observable as funnel cloud attached to a cloud base. Parameters affecting the structure of a tornado vortex include swirl ratio, (radial) Reynolds number, surface roughness, and translational movement. Current findings on the effects of each parameter on structure of tornado vortex were well summarized in Kim and Matsui (2017).

Besides field measurements, indoor experiments and computational simulations, many theoretical and empirical numerical models have been proposed for preliminary tornado-resistant design of buildings and structures. Numerical models include the modified Rankine model, the Burgers-Rott model, the Kuo-Wen model, and the Baker model (Kim and Matsui, 2017). The idealized and inviscid modified Rankine model has been widely used as a first approximation. Numerical models should explain the physical structure of tornado vortices, but there are many weaknesses in existing numerical models in their physical understanding. Comprehensive comparative studies have recently been conducted by Kim and Matsui (2017).

The present paper proposes a new empirical model for a one-cell tornado vortex, and aerodynamic forces on a tall building are calculated and compared with those from existing numerical models. The velocity components of the proposed model show clear variations with radius and height, thus overcoming the shortcomings of existing numerical models. The aerodynamic forces on a tall building obtained from the proposed model show similar values to most existing models, although those from the Baker model show much larger values.

REFERENCES

Kim YC, Matsui M, 2017, Analytical and empirical models of tornado vortices: A comparative study, Journal of Wind Engineering & Industrial Aerodynamics 171, pp. 230-247.

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