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Evaluation of Building Response to Tornado-Like Loading Based on Laboratory Testing of a Building Model

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INTRODUCTION

Tornadoes are among the most devastating windstorms. For this reason, a increasing number of research have been conducted to investigate tornadic loading on structures. Because measurements of loading during the passage of tornadoes remains challenging, most previous research has utilized laboratory testing and numerical simulations of structures in tornado-like winds. It has been revealed that tornado-like loading can be very different from loading by boundary-layer type winds, mainly due to the static pressure deficit caused by the swirling tornadic flows and the nonhomogeneous, nonstationary nature of the loading when a tornado-like vortex passes a structure. It has also been suggested that the loading is influenced by several key factors, including the type of the tornado-like vortex and the speed at which the vortex translates. Despite the advance in the understanding of the loading, however, few studies have been conducted to evaluate the response of structures. In the limited number of studies of structural response to tornado-like loading, the focus was often placed on the worst scenario, or the structural response is only due to a single time history of tornado-like loading. This paper presents a probabilistic assessment of the response of a building to tornado-like winds. The loading is characterized based on testing of a model in a tornado simulator. The characteristics are used as a basis to simulate realizations of the loading which are applied on the prototype building to assess the performance of the building frame.

METHODOLOGY

To characterize tornado-like loading on a low-rise building, a model of the building is tested in a two-celled tornado-like vortex generated by a tornado simulator. In the tests, the orientation and opening configuration of the envelope of the model were varied to evaluate the effects of these factors on the loading. The model was also traversed at two speeds along multiple lines to evaluate the effects of the translation speed of the vortex and the translation path relative to the vortex on the loading. Wavelet transform is used to separate the position varying mean and fluctuating components of the pressures. The mean components are deemed deterministic, and the fluctuating components are used to estimate the statistical moments using Gaussian kernel regression and the evolutionary power spectral density (EPSD) and the cross evolutionary power spectral density (XEPSD) functions of the pressures at different locations using wavelet transform. The moments and the EPSDs are used as a basis to simulate realizations of the pressures using the spectral representation method. The response of the building to the simulated loading is evaluated.

`ILLUSTATIVE EXAMPLE

To illustrate the methods used in the study, 20 repeat measurements of the external and internal pressures acting on the tributary area of a frame of the model with a dominant opening when it translated through the center of the vortex at a speed of 0.75 m/s are used to estimate the loading on the building. Fig. 1 (a) shows the internal pressure coefficient measured during one test run as well as the position-varying mean component obtained through wavelet transform, and Fig. 1 (b) shows the position-varying fluctuating component of the pressure coefficient. The ensemble of the position-varying pressures from repeat tests are used to estimate the EPSDs and XEPSDs, which were used as a basis to simulate realizations of the pressures using the spectral representation method. To illustrate the effectiveness of the simulation, uplift forces are calculated based on both experimental data and the results of the simulation and the EPSDs of which are presented in Fig. 2. Good agreements between the experimental data and result of the numerical simulation can be observed. Simulated loading using the procedure described above are applied to the low-rise building. The response of the building to the loading will be presented in the full paper.

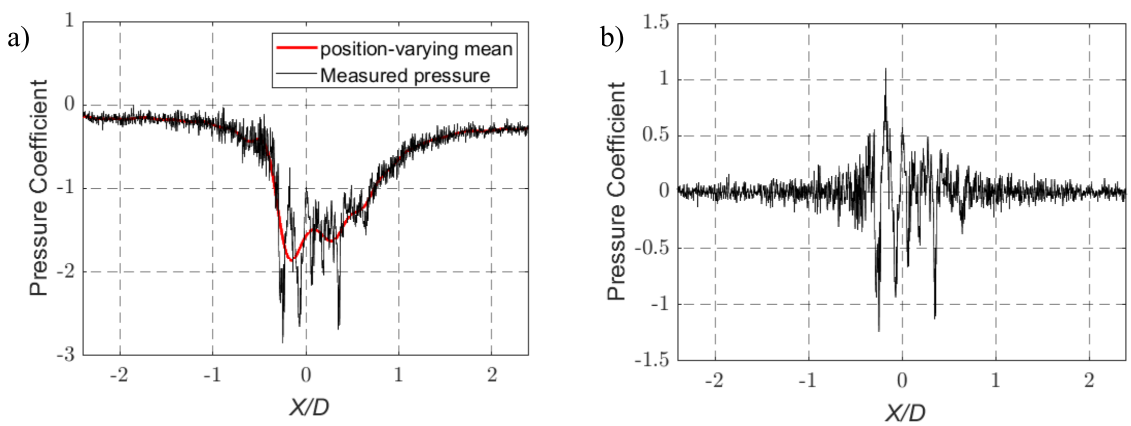

Fig. 1. a) Position varying mean pressure and b) Position-varying fluctuating pressure

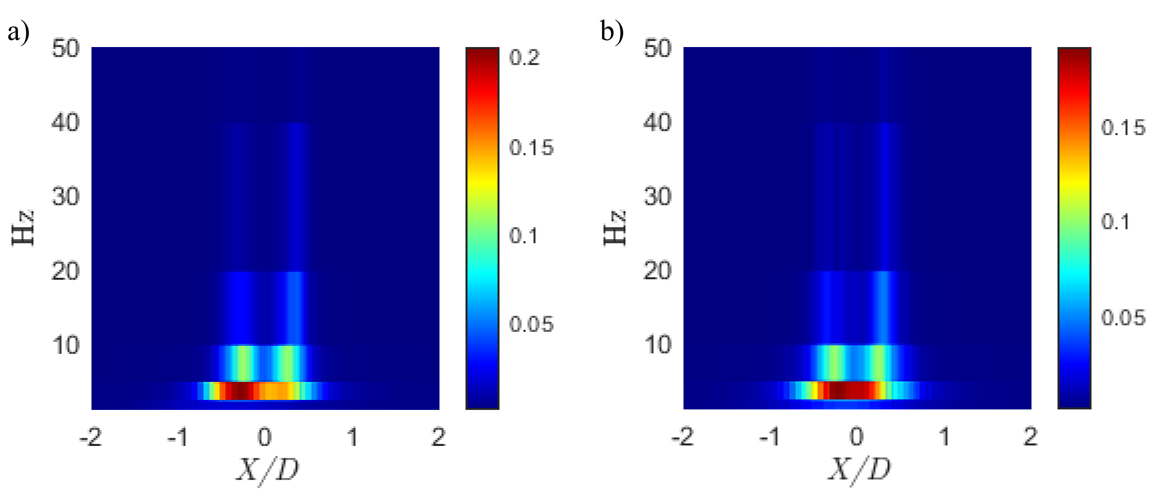

Fig. 2, ESPD of the uplift force based on a) experimental measurements and b) numerical simulations