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Analysis of hurricane wind loads on low-rise structures

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ABSTRACT

Time series of pressure coefficients collected on the roof of a house by the Florida Coastal Monitoring Program during landfall of Hurricane Ivan on the Florida panhandle in 2004 are analyzed. Rather than using peak values, which could vary due to the stochastic nature of the data, a probabilistic analysis is performed to characterize extreme values of pressure coefficients and associated wind loads. It is shown that the pressure coefficient time series follows a three parameter Gamma distribution, while the peak pressure follows a two-parameter Gumbel distribution. The analysis yields a probability of non-exceedance of a given threshold of the pressure or load coefficients. For this specific house and specific storm, the 80 percentile load coefficient value of the probability of non-exceedance is −1.7. This is discussed in the context of ASCE 7 GCp values.

1. Introduction

Despite the appreciable progress made toward a reliable estimation of wind loads on low-rise structures which include full scale measurements and wind tunnel [1–4] and numerical simulations [5], some issues remain unsolved. For instance, pressure and wind load coefficients in building codes are based on experimental values obtained from wind tunnel simulations. These simulations are conducted in long test-section boundary layer wind tunnels. The coefficients are measured on scaled-down models that are placed in turbulent shear layers. Controversies still exist about what constitutes a proper wind tunnel simulation of the turbulent flow of the atmospheric surface layer and associated wind loads on low-rise structures. Particularly, the stochastic nature of the incident wind and associated loads is an issue that should be addressed. These loads can vary depending on the wind direction and speed, as well as the turbulence parameters. They could also vary substantially from one sample to the other, especially in cases where the levels of incident turbulence are large. As such, isolated peak values are not significant because they depend on the record length. More importantly, it is very hard to compare them to peaks from full scale measurements where changes in wind speed and direction are limited and the record length is relatively short.

To this end, data collected from post-hurricane damage investigations on a large number of houses can serve to validate wind tunnel or numerical simulations and design criteria in building codes and standards. This is especially needed because there is evidence that wind damage occurs at wind speeds well below the design wind speed of building codes [6,7]. Considering the stochastic nature of wind loads, the fact that provisions of standards and codes are based on many wind tunnel simulations that may have their own shortcomings, and the availability of full scale data from the Florida Coastal Monitoring Program, it is imperative to develop tools that can be used to compare full scale wind loads with those of standards and codes.

The objective of this work is to use a probabilistic approach to characterize peak loads on a residential structure in a hurricane. Previous studies of this set of data utilized a peak sampling procedure to quantify peak pressure coefficient values in a statistical sense [8]. However, the relatively short time frame associated with the full scale data limited this approach, and non exceedance probabilities could not be provided for various peak value thresholds. Rather than sampling only peak values from the data, the analysis presented here utilizes the entire stationary record to produce an accurate probabilistic model of the peak pressure coefficients. This yields not only a more reliable estimate of peak behavior, but also provides the means to quantify the peaks associated with various probabilities of exceedance. This analysis, which is based on a procedure developed by Sadek and Simiu [9], allows the design of wind-load sensitive parts to be based on more accurate information and should therefore be more

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