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Field measurement and wind tunnel simulation of hurricane wind loads on a single family dwelling

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ABSTRACT

During landfall of Hurricane Ivan on the Florida 'panhandle' in 2004, pressure time-history data were recorded on multiple pressure sensors installed on the roofs of six single-family homes. An analysis approach was developed to determine the peak negative, mean, peak positive, and standard deviation of pressure coefficients for these datasets. This paper presents a comparison of the full scale pressure coefficients from one of these homes, which experienced sustained hurricane force winds, with the results of wind tunnel experiments on a 1:50 scale model of that home. It was determined that the wind tunnel and full-scale mean and rms pressure coefficients matched very closely at almost every monitored location on the roof, while the peak negative pressure coefficients in the wind tunnel study generally underestimated the full-scale values, consistent with observations from previous full-scale/wind tunnel comparative studies. Field-measured hurricane wind loads may prove useful for evaluating existing wind load provisions. However, recommendations in that regard are premature without the analyses of multiple homes in multiple storms, performed by more than one wind tunnel facility. Future work will focus on building such a joint study.

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1. Introduction

Current wind design code provisions in North America were developed using wind tunnel datasets of forces on generic building models [1–4]. Wind loads on low-rise structures have been studied for decades, and the subject is covered in many excellent reviews [5–10]. Full-scale experiments for wind loads on low-rise buildings have helped improve the understanding of the wind/structure interaction, and to validate wind tunnel results Cochran and Cermak (1992), [11–17]. Despite efforts (e.g. [18]), the collection of hurricane force full scale pressure data on typical residential structures sited in suburban neighborhood-type terrain has been elusive. It remains a high priority to obtain full-scale measurements of hurricane wind fields and wind loads to refine the current understanding of the interaction between severe hurricane winds and structures, and to validate or evolve current wind tunnel simulation techniques and results interpretation.

The Florida Coastal Monitoring Program (FCMP) landfalling hurricane data collection project, captured wind velocity and residential rooftop wind pressure data in multiple hurricanes in the 2004 and 2005 seasons [24]. Roof pressure datasets from occupied residential structures measured during sustained hurricane force winds, were analyzed and compared with wind tunnel experiments on scaled models of those homes. A description of the methodology used to measure and analyze full-scale wind pressures and compare them with wind tunnel results is presented for a single family house located in the Florida 'panhandle'.

2. Field data collection program, instrumentation, and subject house (FL-27)

FCMP

The Florida Coastal Monitoring Program (FCMP) is a unique research endeavour, focusing on measurement of near-surface hurricane wind velocity, wind loads on residential structures, and the evaluation of the effectiveness of residential retrofits. The FCMP portable meteorological towers are designed to collect wind velocity data at 5 m and 10 m heights, as well as barometric pressure, temperature, and relative humidity during a landfalling storm. A second FCMP field data collection system measures pressures at multiple locations on the rooftops of occupied residential structures. Subject houses are pre-selected and outfitted to receive the

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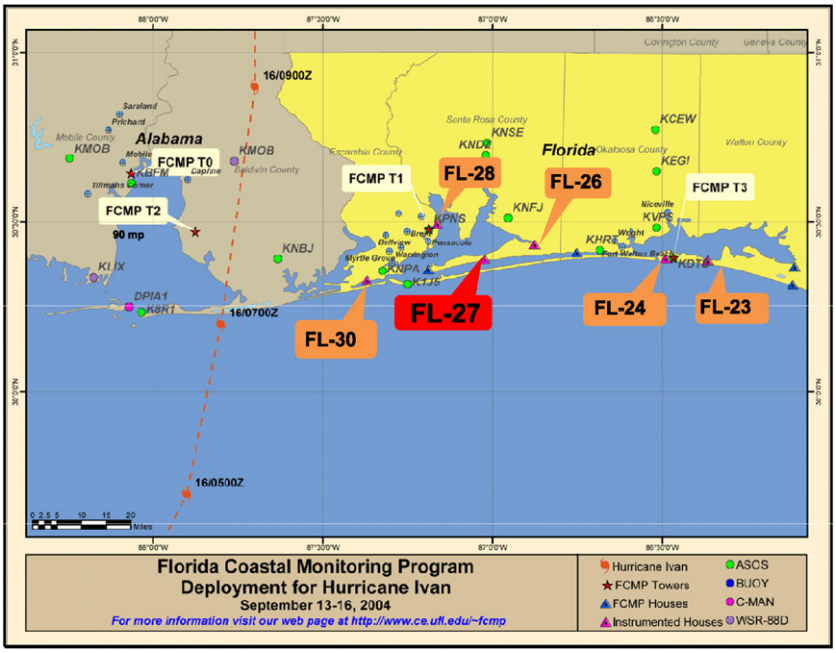

Fig. 1. FCMP deployment map for Hurricane Ivan, 2004.

pressure sensors, which are installed within days prior to a landfalling hurricane. These homes are upgraded with retrofits to reduce their wind vulnerability. More detail on the FCMP instrumentation program development, deployment, and data analysis can be found in [32,27,30,25,26,24,28].

Hurricane Ivan

Hurricane Ivan (2004) made landfall at Gulf Shores, Alabama around 0700 (UTC) on 16 September 2004, approximately 75 km west of the subject house designated FL-27. The highest official sustained wind speed measured at the Pensacola Naval Air Station at landfall was 39 m/s, with wind gusting to 48 m/s. Hurricane Ivan progressed inland across eastern Mobile Bay in a north northeasterly direction at a forward speed of 5–7 m/s, weakening to a tropical storm 12 h after landfall [33].

Subject house FL-27

FL-27 is one of 42 homes in the FCMP program, and one of six houses that were instrumented during hurricane Ivan. Four mobile FCMP wind towers were deployed as well (Fig. 1). FL-27 is a one-story single-family residence located in Gulf Breeze, Florida. It is situated 8.0 m above sea level within a suburban neighborhood of similar-sized homes. The neighborhood is bounded on the east, west and south sides by pine forests (Figs. 2 and 3), approximately 850 m inland from the Gulf of Mexico coastline. The exposure terrain can be categorized as suburban in accordance with ASCE 7-05 [23]. The gable roof consists of multiple levels, with the main ridge at 6 m elevation above grade (Fig. 4). Typical roof slopes were 20°.

Instrumentation

Twenty-four absolute pressure transducers were mounted at corner and edge locations on the roof to measure external dynamic pressures. An additional absolute pressure sensor is connected to an RM Young pressure port to minimize dynamic wind pressure. This unit is mounted 0.9 m above ground on the property, as far from the house as practical, to provide a barometric pressure reference. Two 3-cup Gill anemometers were mounted on the roof, 1.4 m above the ridge (Fig. 4). Fig. 5 presents a roof plan of the FL-27 house showing the locations of the rooftop pressure sensors on the wind tunnel and on the full-scale house.

Each pressure sensor unit consists of a Microswitch 142 PC 15-A absolute pressure transducer installed in a 300 mm diameter

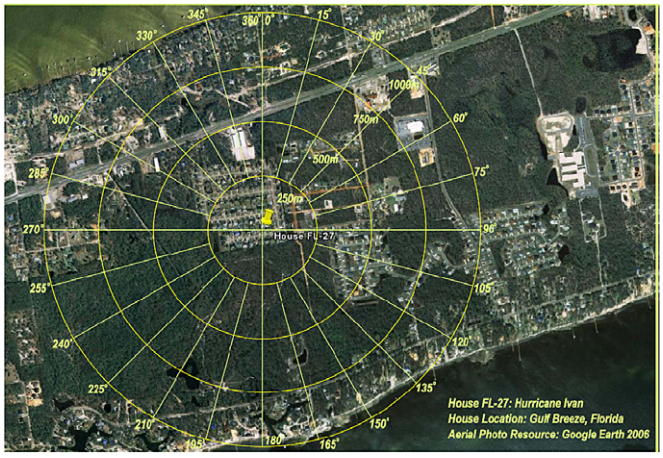

Fig. 2. Aerial view of the terrain surrounding House FL-27 (Courtesy of Google Earth).

Fig. 3. Aerial view of the House FL-27 and neighboring houses (Courtesy of Google Earth). Circle indicates the extent of turntable for wind tunnel experiments.

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