Investigation of the Effects of Extreme Wind Events on Civil Structures

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ABSTRACT

Due to global warming, some experts believe that wind events are increasing in frequency and intensity. The ability to estimate the potential damage of a building or group of buildings due to the effects of extreme wind events, such as, hurricanes and tornadoes is becoming more important. Wind damage bands are used to predict the probable maximum damage degree of a building or group of buildings. The damage estimation model utilizes an objective weighting technique incorporating component cost factors, conditional failure probabilities, and location parameters to develop wind damage bands. Recently, damage bands have been incorporated into loss estimation software developed by the government and private companies. Understanding how a structure performs during a hurricane is a powerful tool that is important in determining what needs to be done to minimize losses from these wind events. The component fragilities of the damage estimation model developed by Christian Unanwa were analyzed and altered to test the robustness of the model.

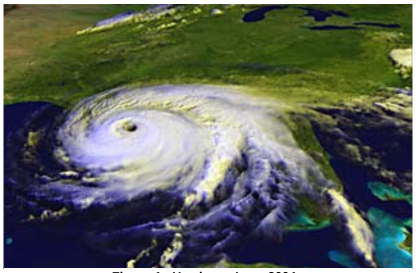


Figure 1. Hurricane Ivan, 2004.

BACKGROUND

The Southeastern region of the United States is prone to hurricanes each year. These natural disasters with ranging intensities can cause damage from bent and broken signs to the near destruction of residential structures. In 1992 Hurricane Andrew was one of the most deadliest and costly storms in recent history. It caused about $26 billion in damages in South Florida and Louisiana (NOAA). The majority of the damage caused by Andrew was from wind damage.

The 2004 hurricane season in which the insured losses in the State of Florida from four hurricanes, Charley, Frances, Ivan, and Jeanne, surpassed Andrew and became the costliest hurricane season in history. The 2004 season caused about $23 billion in insured losses compared to Andrew's total of $15.5 billion in 1992 (Insurance Journal, 2004). Florida Statutes Section 215.559 created the Hurricane Loss Mitigation Program, which funds the Residential Construction Mitigation Program (RCMP). Through the RCMP, the Legislature appropriates money annually to improve the wind resistance of residential structures. With an increase in public awareness about various mitigation techniques after the 2004 hurricane season, homeowners are more inclined to utilize mitigation techniques to reduce losses in future events.

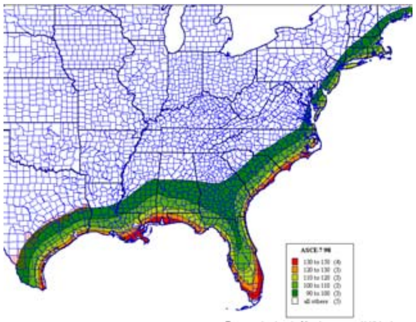


Figure 2. Hurricane Prone Regions of the U.S.

OBJECTIVES

The main objective of this research is to update the statistical distributions used to determine the conditional probabilities of failure of the building components used in the damage estimation model. These updates are needed to reflect the advancements of hurricane mitigation techniques and incorporate them into the damage model.

METHODOLOGY

A model for the probable maximum loss for wind damage to buildings was proposed by Unanwa. The model uses damage bands, which define the degree of damage for a specified hazard level *l*, to estimate the degree of wind damage sustained by buildings. The damage function used to estimate the damage degree is defined as:

$$DD(l) = \sum_{i=1}^{n} P_{f_i}(CCF_i)\alpha_i \qquad (1)$$

where $DD(l)$ is the damage degree at hazard level l, P_{fi} is the component fragility, CCF_i is the component cost factor, α_i is the component location parameter, and n is the number of components.

The cost factor (CCF) relates the degree of damage of one component to the degree of damage to entire building and can be expressed as the ratio of the replacement value of the component to the replacement value of the building. The location parameter accounts for the distribution and location of components in relation to their degrees of wind damage. The component fragility is defined as the relationship between the conditional failure probability of the component and hurricane intensity. The component fragilities are expressed as:

$$P_{fi}(l) = P_{fi}^{B} + P_{fi}^{P} - P_{fi}^{B}P_{fi}^{P} \qquad (2)$$

where P_{fi}^{B} and P_{fi}^{P} represent the basic (direct) and propagational (indirect) probability of failure. The conditional probability of failure, $P_f(l_i)$, of a component is a function of the strength of the component and the amount of the load applied. For deterministic values of li, and random-fixed strength variable it is defined as:

$$P_f(l_i) = P(R \le l_i) = \int_{-\infty}^{l_i} f_R(r)\,dr = F_R(l_i) \qquad (3)$$

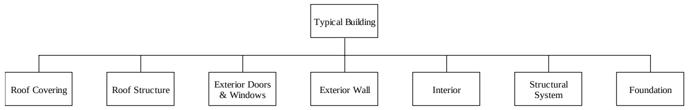
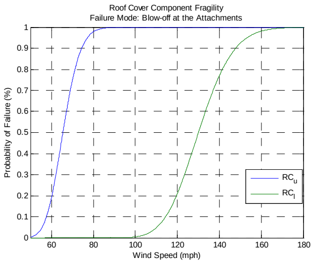


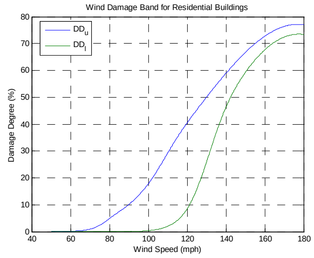
Figure 3. Building Characterization by Components

PRELIMINARY RESULTS

Table 1. Building Characteristics for Upper & Lower Bound Fragilities

Component	Failure Mode Modeled by	Properties for Upper Bound Fragility	Properties for Lower Bound Fragility
Roof Covering (RC)	(1) Blow-off at the attachments	Asphalt shingles stapled @ 12 in. o.c.	Flat concrete tiles fastened with 6d common nails @ 6 in. o.c.
Roof Structure (RS)	(2) Roof sheathing failure by fastener pull-out	OSB, 15/32 in. thick, fastened with 6d common nails @ 12 in. o.c., 24 in. frame supports	Plywood, 19/32 in. thick, 5-ply, fastened with 10d common nails @ 6 in. o.c.
	(3) Uplift at roof-to-wall connection	Wood rafters @ 2ft. o.c. nailed to wall plate with 3 no. 16d box nails	Roof frame fastened to wall with no. H7 Simpson Strong Tie
Exterior Doors & Windows (EDW)	(4) Breakage by windborne missiles	Annealed glass, 3/15 in. thick	Highly tempered glass, ¾ in. thick





ACKNOWLEDGEMENTS

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