A Proposal for Development of Wind-Driven Rain Climatology and Coincidental Wind Speed Return Period Maps for Florida and Adjacent Coast Areas

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Introduction

Rain water intrusion, in its various forms, persists as one of the most costly and prolific forms of damage to buildings in the United States (Carll, 2000; ASTM, 2009; HUD, 2015). For exterior walls, rain water intrusion is closely related to the presence of wind to cause rain water impingement on walls. More importantly, the coincidental presence of wind also causes wind pressure differentials that force water behind claddings and into or through wall assemblies or components. This mechanism of rain water intrusion is prolific and is the cause of substantial economic impact, loss of building resiliency and useful life, and even has structural safety implications.

In the most severe and obvious cases, the damage is immediate and extensive as in tropical storms and hurricanes, even without the presence of significant damage to the structure or its exterior finishes. This form of damage can extend to building contents which escalates the cost impact. Less obvious forms of damage occur more insidiously from routine thunderstorms and other wind-driven rain events that impact Florida, other coastal locations and even inland areas across the United States. In these cases, water may be driven into assemblies without noticeable damage to building interiors. Consequently, the damage accumulates and progresses unnoticed until significant rot or corrosion or mold damage occurs within building assemblies. In the worst-cases, structural damage may go undetected and progress until exposed by a loading event resulting in failure or collapse. This collective impact of wind-driven rain impacts the durability and resiliency of essentially all of the U.S. building stock. Yet, there is no risk-consistent basis for dealing with this wind-driven rain hazard as it varies across Florida much less the United States.

In the absence of a scientific understanding of wind-driven rain hazard as a risk-consistent basis for controlling the potential for rain water intrusion, building codes and construction practices have been developed in an inconsistent fashion based on experience and traditional practices. These practices may work well in some climates (e.g., dry southwest), but perform poorly in others (e.g., the Florida, Gulf and Atlantic Coasts, or inland regions impacted by frequent thunderstorms). In addition, newer alternative materials and methods for weather resistance may be developed on the basis of "equivalency" to these accepted practices without a risk-consistent or uniform set of performance requirements. Thus, they become subject to the same lack of risk consistency in preventing water intrusion due to wind-driven rain.

This problem and its consequences will continue and persist without the development of a wind-driven rain climatology that properly represents the variation in wind-driven rain hazard across Florida and by extension the United States. This need must be addressed in a manner that can be implemented to determine appropriate and consistent performance metrics for design and evaluation (testing) of building enclosures for weather resistance. This proposal will be aimed at addressing this climate hazard need in a scientifically robust and practical manner.

Background

Interest in addressing wind-driven rain is not new and past attempts to resolve this concern in the U.S. have failed, largely due to the lack of a well-defined hazard basis to justify solutions to the problem. For example, a recent U.S. model building code proposal, numbered FS93-18, attempted to establish a risk-consistent basis for addressing wind-driven rain resistance of building envelopes (ICC, 2018). However, the proposal failed in large part due to the use of an old wind-driven rain "index map" which does not properly account for the coincidental occurrence of rain and wind. In other cases, annual rain fall data have been used as a basis for roughly describing regions of the U.S. with differing water intrusion hazard, although without consideration of coincidental wind speed necessary to produce rain impingement and pressure differentials that force intrusion. A risk-consistent basis for defining the variation in wind-driven rain hazard across the U.S. is needed to support building code advancement.

Various standards and criteria for evaluation of critical building envelope weather-resistant components, such as windows and water-resistive barriers, are generally prescriptive and vary significantly in the degree of water-intrusion resistance required for building code approval (ABTG, 2015). This lack of consistency in criteria creates uncertain and varied performance for different types of products and materials that are intended to serve the same purpose. Hence, market and product development problems have surfaced and now persist because of the lack of a risk-consistent and uniform basis for defining performance requirements for all components that work together to provide weather-resistance to building envelopes. A risk consistent basis for defining the variation in wind-driven rain hazard is needed to support appropriate standards and criteria for assessing and specifying building products, materials, and assemblies.

Research Approach

The University of Florida will serve as the project manager, leading the project, in cooperation with representatives of Cornell University and the Insurance Institute for Business & Home Safety (IBHS).

Progress has been made in other countries on the matter of defining wind-driven rain hazard. For example, Canada uses a driving-rain wind pressure (DRWP) parameter based on analysis of climate data in a manner similar to that which is proposed (CSA, 2009). The DRWP is used to evaluate and specify window and door products suitable to a given climate in Canada. A similar, coordinated effort is needed in Florida and more broadly the U.S., to ensure building envelope components are specified in a manner consistent with the environment in which they are intended to be used.

This research proposes to deliver such data in the form of wind-driven rain hazard maps, focused on Florida and adjacent coastal areas that experience similar hurricane and wind-driven rain climatologies. It will build upon a pilot effort, that will evaluate wind-driven rain risks outside of Florida, thus assuring that a consistent methodology will result in a risk standard that is applicable across the U.S. and Canada. It is anticipated that the mapped data will present wind speed return periods based on analysis of weather station data for annual extreme wind speeds that occur ***in coincidence*** with a relevant range of threshold values for coincidental rainfall rates. The threshold rainfall rates will be chosen to bracket conditions considered representative of that minimally necessary to initiate consequential leakage into or through building envelopes. Following Masters et al., (2010), The wind speed data will be adjusted as necessary to align with baseline design conditions (e.g., open, flat terrain, 33-ft above ground) such that standardized wind design provisions such as ASCE 7 (ASCE, 2016) can be used to determine pressure differentials across a building envelope that are coincidental with rainfall of a given threshold rate.

Past national assessments of WDR have relied on meteorological data collected at hourly resolution. This is problematic in that it is likely that the highest wind speeds and rainfall intensities occur at shorter time scales and thus are not reflected in the hourly data. Blocken and Crameliet (2010) advocate for the use of 10-minute resolution data, although in some cases hourly data (reflecting the average of 10-minute measurements) was found to be adequate. Ge (2015) showed that while the correlation between WDR obtained from hourly data and that using

5-minute data was high (> 0.95), values based on hourly were on the order of 6% higher than the 5-minute reference.

Research Analyzes Data in 5-Minute Intervals

In our work, we will propose to use data at 5-minute temporal resolution. The data is available back to 2000, at nearly 50 National Weather Service stations in Florida. Data from dozens more sites with similar hurricane climatologies will be obtained from adjacent states and U.S. territories in the Caribbean. Using these data, we will be able to identify nearly coincident periods of high sustained winds and rainfall. We will also be able to aggregate 5-minute data over longer averaging period, to assess differences between this new data resource and climatologies based on hourly records. Based on this comparison, we also propose to examine whether a strong enough relationship exists between the more desirable 5-minute wind-driven rain data based at an hourly resolution. If such a relationship is feasible, the period of record available for analysis can be extended back to at least 1950 at most stations. Otherwise, only the shorter (approximately 20 years) 5-minute data will be used to develop extreme wind driven rain climatology. This will be a sufficiently long record to assess recurrence probabilities on the order of 25 to as much as 50-years.

Anticipated Deliverables

1) Quality control algorithms to identify erroneous data values. We will implement a set of limit checks to flag data values that exceed published 1% recurrence probabilities of rainfall and windspeed. These flagged values will be manually screened to assure their veracity.

2) A set of contour plots, one for each station. These plots will document the mean recurrence intervals (mri) consistent with mris used to develop ASCE7 Chapter 26 wind speed maps, of simultaneous wind-speed (x-axis) and rainfall intensity (y-axis) during the available 20-year record of 5-minute observations.

3) A set of contour plots, one for each station but for the longer record of once-per-hour rainfall and windspeed observations. In actuality this deliverable will consist of two sets of contour plots. One using the same period of record as the 5-minute data, the other using the longer 50-year period-of-record that is available for the hourly data This will allow direct comparison between the probabilities computed using data with different temporal resolution as well as an assessment of the effect of the longer period of record.

4) Contoured maps showing a specific wind speed recurrence interval values conditional on rainfall intensity covering Florida and adjacent coastal areas. For example, the 4% annual probability of 5-minute windspeed conditional upon the occurrence of rainfall within an intensity category.

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