RICOWI, Inc.

Roofing Industry Committee on Weather Issues, Inc.

Hurricanes Charley and Ivan Wind Investigation Report

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In cooperation with the

OAK RIDGE NATIONAL LABORATORY
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UT-BATTELLE

EXECUTIVE SUMMARY

The investigation report of Hurricanes Charley and Ivan is the fruition of 10 years of planning for a major wind event that met the criteria of the Roofing Industry Committee on Weather Issues, Inc. (RICOWI) membership. The Wind Investigation Program (WIP) was initiated in 1996 with these major objectives:

- To investigate the field performance of roofing assemblies after major wind events
- To factually describe roofing assembly performance and modes of failure
- To formally report the results of the investigations and damage modes for substantiated wind speeds

The goal of the WIP was to perform unbiased, detailed investigations by credible personnel from the roofing industry, the insurance industry, and academia. Data from these investigations will, it is hoped, lead to overall improvement in roofing system durability and a reduction in insured losses, which may lead to lower overall costs to the public. Two major hurricane events in 2004 finally provided the opportunity for execution of the WIP plan. This report documents the achievement of the objectives through execution of an extensive and well-planned investigative effort. Estimated wind speeds at the damage locations came from simulation of the hurricane wind fields along the paths by the Hurricane Research Center and others.

Hurricane Charley made landfall near the Punta Gorda–Port Charlotte area of Florida as a Category 4 hurricane on Friday, August 13, 2004. Charley was the first storm to meet the RICOWI WIP criteria of “greater than 95 mph sustained wind speeds over a populated area.” Seven teams involving a total of 39 persons fanned out over the area to document damage to both low slope and steep slope roofing systems. The teams collected specific information on each building examined, including roof shape, roofing system materials, edge conditions, installation details, and degree of deterioration, if any. With each team member assigned a specific duty, they described the damage in detail and illustrated important features with numerous colored photographs. Where possible, the points of damage initiation were identified, along with possible reasons for the initial failure. Owing to their extensive experience and knowledge of roofing technology, succinct observations and assessments were made as team members identified causes of failure and the consequences.

Hurricane Ivan made landfall on September 16, 2004, west of Pensacola, Florida, as a Category 2 hurricane. Five teams (21 persons) conducted an extensive wind damage investigation, again looking at low slope and steep slope roofing systems. The personnel gained valuable experience in the Charley investigation, which is reflected in the Ivan report. The same general format is used in the Ivan report.

LOW SLOPE

Wind-related damage conditions observed on the 93 roofs ranged from minor to extensive. Damage conditions included loss of edge metal; punctures/tears in roof membranes; withdrawal and pull-over of securement fasteners; and, at some locations, complete displacement (blow-off) of the roof system.

The roofs exhibited some commonality in where wind damage began, how damage progressed, and causes of damage. Events believed associated with initiation of wind damage included the following:

- Lifting of edge metal (cleat deformation or absence, and flashing disengagement)
- Billowing of membranes and membrane base flashings (air infiltration into spaces behind base flashings and below roof membranes)

- Puncturing/tearing of the roof membrane from wind-borne debris and wind-toppled equipment
- Release of deck panels from attachment points

Scenarios of how wind damage progressed from initiation points included the following:

- Membrane billowing, fastener pull-out (at termination bars and sheathing boards), displacement of sheathing boards and/or base flashings, and membrane tearing and/or peeling at fasteners
- Edge cleat deformation, edge metal deflection, edge metal and/or nailer lifting, and roof membrane tearing (around fasteners) and peeling
- Debris puncturing membrane, wind billowing membrane near puncture, and membrane tearing (mechanically attached single-ply roofs only)

Conditions most often associated with damage observations included these:

- Deteriorated roof attachment systems (resulting in a reduced wind uplift resistance)
  - Corroded fasteners
  - Deteriorated wood substrates
  - Deteriorated mechanically attached base sheets
- Roof constructions that varied from common industry recommendations
  - No increase of mechanical attachment in perimeters or corners to compensate for increased loads as specified in ASCE 7 and FM-1-29
  - Edge metal cleat gauges and wood nailer securement less than recommended in FM Global LPDS 1-49 (1979) and ANSI/SPRI ES-1 (adopted in 2003 IBC)
- Roof constructions that included openings that allowed rapid air infiltration between roof membranes and roof decks
- Locations exposed to wind-borne debris

STEEP SLOPE

Wind-related damage conditions observed on 91 steep slope roofs ranged from minor to extensive. Damage conditions included insufficient attachment, component detachment, and complete displacement (blow-off) of the roof system. Workmanship and improper material selection issues were major factors in the observed damage.

The roofs exhibited similarities in where wind damage began and how the damage progressed. Events believed associated with initiation of wind damage included the following:

- Insufficient attachment: Insufficient fastener attachment was commonly observed in both the types and the number of fasteners used.
- Insufficient fasteners: Cases were observed where the fastener was not sufficient, in conjunction with the frequency of placement, to resist the wind forces.
- Inappropriate fastener placement: Examples of roof failure occurred where fasteners and placement patterns were used that would not normally have been specified or prescribed for a particular application.
- Building code changes: It was found that the fastening requirements specified in a later version of the building code were an improvement over those of the earlier code. Insufficient attachment was also prevalent in the securing of substrates and framing members.
- Workmanship. The teams observed instances where the construction of the roof covering compromised its performance against the hurricane-force winds. Cases were found of missing or improperly placed fasteners. Other cases were found where the construction of the building's roof covering was not according to the governing code or standard practice at the time of construction.

- Improper material selection. Examples were found of roofs where either one component or a combination of components failed to withstand the force of winds. The failure of one component used on the roof or as part of the roof structure was found to influence the performance of other materials. Roofs that were exposed to and survived the hurricane winds were supported by an entire system having the required materials installed according to specification.
- Structural failure. Cases were observed in which the structural integrity of the building was breached and the roof failed.
- Age and maintenance. In some cases in which similar material types were used, newer roofs performed better in the hurricanes than did older materials. Some of the performance differences between older and newer materials can be attributed to better-specified application methods; but in similar roofs with equivalent application methods, it was observed that newer roofs fared better than older ones. Examples were found in which the performance of the roof was weakened by corrosion or deterioration of components.
- Winds in excess of code design. In some instances, the roof system failed even though it was constructed according to an appropriate updated specification. These examples were found for both the roof covering and the building's structure.

The data and the subsequent assessments will hopefully be used by product manufacturers, roofing system designers, roofing contractors, and building officials to improve the performance of roofing systems in high winds. The efforts expended by the team members, the financial support from all the contributors, and the help of the sponsoring organizations will no doubt be of great benefit to the roofing industry in the future.

RESULTS

The investigation of Hurricanes Ivan and Charley provided valuable information on the performance of roofing exposed to hurricane-force winds. The investigation teams were able to discern the effectiveness of materials and methods of construction in resisting these winds. A variety of damage modes were observed in the hurricane-struck areas, including roof attachment, material selection, roof/structure design, deterioration, and workmanship. Many of the performance characteristics observed in Hurricane Charley were again observed in Ivan. During the investigations of Ivan and Charley, our teams found that generally roofing installed according to the latest codes resisted damage from the winds. The information gathered on some types of materials provides an understanding of the materials' performance characteristics when installed in accordance with the customary method for that area. The participating associations will develop specific recommendations for new installation procedures and building code changes based on the data and reports.

The investigations were also a learning laboratory for the investigation procedures used. It was clearly shown that investigations need to be under way soon after landfall to capture the progression of damage. Repairs of essential facilities are usually under way as soon as the debris can be adequately cleared and access is available. A preliminary assessment team with flyover and aerial photo capabilities provides the information that allows the best use of resources in the investigations. This is most important in locating low slope rooftops that cannot be observed from the ground. Logistics is critical to successful investigations. Housing near the inspection area, although difficult to obtain, led to effective use of the manpower resources provided in these investigations.

Installation of roofs systems as a minimum should meet the minimum code requirements in hurricane zones and follow best industry practices and manufacturers' guidelines. Owners and specifiers are urged to consider designing systems that exceed current code requirements. Systems should follow the performance requirements, including appropriate testing, specified by the applicable building code.

All building envelope components are affected by weather-related aging; therefore, sufficient maintenance of buildings is important. The studies reinforced the need for secure roof edges, and codes that require secure roof edging need to be enforced. Wind-borne debris was also a major contributor to roof damage, and standards and enforcement are needed for attachment of all building envelope components to help reduce wind-borne debris (e.g., air handling units).

FUTURE RESEARCH

Future hurricane wind investigations would prove valuable in collecting additional information on the performance of roofing exposed to hurricane force-winds. Some questions or suppositions were resolved from information gathered during the Charley and Ivan events; but, at the same time, other questions surfaced. For example, it was observed that some roofing materials were more prone to damage when located on gable-constructed homes or around wall protrusions or dormers. More investigations are necessary to verify these and other observed phenomena. Although an effort was made to investigate all types of roofing, some types were not found in the areas affected by Charley and Ivan. Therefore, further investigation is warranted in areas that contain other types of roofing or construction methods not previously observed.

In particular, it would be valuable to conduct an additional survey in the same areas previously investigated by our teams, or in a location that had recently been rebuilt after a hurricane. Also of interest would be investigations in areas that have installed substantial amounts of roofing in accordance with the latest code revisions. Questions regarding the adequacy of the building code arise after an area is ravaged by a hurricane, and investigations are warranted when serious questions are raised by governing authorities. Investigations can distinguish whether the damage is caused by non-conformance to code standards or if the code is adequate. The goal of RICOWI investigations is to gather the facts, and facts are necessary when there is a general push for change that is perhaps fueled by supposition or concerns raised by false information. The unique, balanced composition of RICOWI teams (members from industry, science/research, and consultation) results in the documentation of facts without bias.

RICOWI investigations are conducted with a forensic scope and are not intended for statistical analysis, but the investigation criteria in future events might be amended to allow for larger samplings. Other search criteria could be added, as appropriate, to gather information not previously considered. The criteria for event mobilization could be modified according to the information that might be desired from a particular area impacted by a hurricane. In other words, in the future, the decision regarding whether to activate for an investigation can be based more on the potential value of the information to be gathered, rather than the prior criteria based on a hurricane with 95-mph (one minute sustained) winds striking any major populated area in the continental United States.