

Water Entry Through Attic Vents

By Stephen L. Quarles, PhD; Tanya M. Brown, PhD; and Anne D. Cope, PhD, PE

INTRODUCTION

Recent testing at the Insurance Institute for Business and Home Safety (IBHS) Research Center provided an opportunity to quantify the amount of water entry that occurred through selected attic vents commonly used in residential construction during simulated wind-driven rain exposures.

Water penetration can cause extensive damage to interior finishes and can lead to ceiling collapse when attic insulation is saturated. When power is lost and/or a house cannot otherwise be dried out within 24 to 48 hours, additional moisture-related difficulties are common, extending the time during which the property may not be available for use. IBHS researchers investigated whether adopting installation methods for soffit covers that reduced the chance of detachment during high-wind events could reduce human inconvenience and financial costs associated with water entry during hurricanes. Additionally, IBHS testing investigated water entry through gable end vents. The Research Center testing was an extension of work done following an IBHS post-disas-

ter field investigation into damage caused by Hurricane Charley in 2004, after which IBHS developed recommendations and procedures for installing soffit material.¹

EXPERIMENT

A full-scale duplex building was designed and constructed for this study. The building included gable ends fitted with nominal

1.5- x 2-ft. (0.46- x 0.6-m) gable end vents and nominal 1-ft. (0.3-m)-wide soffits at the eaves. In this series of tests, water entry through the soffit material (both installed and not installed) and through gable end vents was evaluated (Figure 1). A wind-driven rain deposition rate of 8 in./hour (203 mm/hour) was used. This rate was based on the value specified for wind-driven rain



Figure 1 – End view of the building, showing location of gable end vent (open) and soffited eave. Note: Some of the panels have detached as a result of exposure to the elevated wind speeds.



Figure 2 – Water collection channels between ceiling trusses in the attic of the test building.

Figure 3 – Water collection system inside the test building.



in ASTM E331-00. Wind speeds of 30, 50, and 70 mph (13.4, 22.4, and 31.3 m/s) were used.

In the first three tests (Table 1, Tests 1-3), water entry through the eaves was evaluated with no soffit material installed, to simulate a case where the soffit covering (see Figure 1) detached during a high-wind event. Subsequent testing was conducted after the perforated vinyl soffit covering was installed (Table 1, Tests 4-8). Water entry through the gable end vent was also evaluated with (Table 1, Tests 3-4) and without (Table 1, Tests 1-2 and 5-8) a plywood covering attached to the outside of the gable end vent. Additional testing details are provided in the Testing Program section of this article.

Establishing Wind-Driven Rain Capabilities

IBHS provided financial support to the University of Florida (UF) to assist with deployment of a research disdrometer during Hurricane Ike in 2008 to measure and record the size distribution of rain-

drops. UF developed a novel instrumentation platform that continuously aligned the disdrometer with the mean rain direction to take measurements of rain droplets in extreme winds. Additional financial support was provided by IBHS for a graduate student to analyze the rain droplet size distributions from the data and to use the UF wind simulator to select a commercially available spray nozzle that would produce a similar distribution of rain droplet sizes. Matching droplet size is critical because the

momentum of large drops will cause them to ignore the effects of wind flow around the building, while tiny drops will simply follow the flow and not wet the surface of the building. Prior to conducting the water entry measurement testing, validation tests were run in the large test chamber at the IBHS Research Center using the same research disdrometer.

Measuring Water Entry Rates

Drainage panels and tracks (DrySpace™)

were installed in the attic of the test building to create water collection channels between the ceiling trusses, as shown in *Figure 2*. These channels were outfitted with drains and pipes that allowed water to be collected in plastic containers arranged throughout the interior (nonattic) space in the two halves of the building. The drainage system was installed so that the collected water could be segregated by zones. These zones were roughly 10 ft. (3 m) long by 2 ft. (0.6 m) wide. The trusses extended from the front to the back of the test building. The between-truss spacing was divided into three sections, each about 10 ft. (3 m) long. Typical drain and collection locations are shown in *Figure 3*. Each test was conducted for a 20-minute period, during which a constant wind speed was maintained. At the completion of each test, water in the buckets was measured and recorded.

Testing Program

Summaries of the testing program are provided in *Tables 1* and *2*. The first sequence of tests, designated as the removed/open soffit tests, involved measuring water entry when the soffit cover was missing along the entire length of the back eave of the building (*Table 1*, Tests 1 - 3). The gable end vent was uncovered during Tests 1 and 2 to promote airflow in the attic and was covered with plywood during Test 3 (the quartering wind test) to limit water entry to the open soffit. The open under-eave area along the wind-driven, rain-exposed face of the test building was approximately 37.5 sq. ft. (3.5 m²). The second series of tests, designated as the installed soffit tests, involved measuring water entry with a perforated vinyl soffit material installed (*Table 1*, Tests 4 - 6). The perforated vinyl soffit material consisted of uniformly spaced holes, each 0.125 in.

Test No.	Test Duration, s	Wind Speed, m/s	Perforated Vinyl Soffit Condition	Gable End Vent Condition	Building Orientation	Dominant Water Entry Options
1	1,200	22.4	Removed (Open)	Uncovered	Normal to back of building	Open soffit
2	1,020 ¹	31.3	Removed (Open)	Uncovered	Normal to back of building	Open soffit
3	1,200	22.4	Removed (Open)	Covered	Quartering wind	Open soffit
4	1,200	22.4	Installed	Covered	Quartering wind	Soffited eave
5	1,200	22.4	Installed	Uncovered	Normal to back of building	Soffited eave
6	1,200	31.3	Installed	Uncovered	Normal to back of building	Soffited eave
7	1,200	22.4	Installed	Uncovered	Normal to end of building	Gable end vent and soffited eave
8	1,200	13.4	Installed	Uncovered	Normal to end of building	Gable end vent and soffited eave

¹The duration of Test No. 2 was 180 seconds shorter than the other tests because the water collection system had reached its capacity.

Table 1 – Summary of under-eave and vented opening water entry tests.

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Building Orientation (relative to wind direction)	Gable End		Soffit	
	Vent Covered	Vent Uncovered	Vented Soffit Material Installed	Vented Soffit Material Not Installed
Normal to Back of Building		X	X	X
Quartering Wind	X		X	X
Normal to End of Building		X	X	

Table 2 – A summary of gable-end and soffit-eave condition during the water entry tests.

Wind Speed, m/s	Opening Condition and Building Orientation				
	Open Soffit		Perforated Vinyl Soffit		Gable End
	Head On (0°)	Cornering (45°)	Head On (0°)	Cornering (45°)	Head On (90°)
	Accumulation, mm/hr (%) ¹		Accumulation, mm/hr (%) ¹		Accumulation, mm/hr (%) ¹
22.4	33.0 (16)	40.6 (20)	1.9 (1)	1 (0.5)	~200 (100)
31.3	73.7 (36)	-----	17.3 (8)	-----	-----

¹Percent entry relative to the target wind-driven rain deposition rate of 203 mm/hr (8 in./hr).

Table 3 – Water entry measurements for the eave and gable end conditions.

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(3 mm) in diameter. Testing with the covered soffit was conducted when the building was perpendicular to the wind direction and also at 45° off perpendicular to the wind direction (a quartering wind). The third test sequence evaluated water entry through the open gable end vent when the gable end of the building was perpendicular to the wind direction (Table 1, Tests 7 and 8). In each of these tests, the perforated soffit was installed. These tests were conducted with 30- and 50-mph (13.4- and 22.4-m/s) wind speeds.

RESULTS AND DISCUSSION

The amount of water that entered into the attic space, as a function of the area of the opening, is shown in Table 3. A wind speed of 50 mph (22.4 m/s) produced an overall water entry rate into the attic of about 33 mm/hr based on the area of the soffit. This was about 15% of the total rainfall of 8 in./hr. (203 mm/hr) deposited on the adjacent vertical wall surface. Most water was deposited within the first 10 ft. (~3 m) of the attic space immediately adjacent to the open soffit. A wind speed of 70 mph (31.3 m/s) produced an overall water entry rate into the attic of about 2.9 in./hr (74 mm/hr) based on the open area of the soffit. This was a little more than 33%

of the deposition rate on the vertical wall surface. A quartering wind of 50 mph (22.4 m/s) produced an uneven distribution of water in the attic, but still resulted in about 1.6 in./hr (40 mm/hr) based on the open area of the soffit. This was about 20% of the deposition rate on a wall surface facing the wind flow.

During the test with the perforated soffit cover installed, a wind speed of 50 mph (22.4 m/s) resulted in water accumulation in the attic space of approximately 6% of the amount of water that entered during the same test for the open-soffit case. A wind speed of 70 mph (31.3 m/s) produced about nine times more water accumulation in the attic than the lower 50 mph (22.4 m/s) wind speed test. This was about 25% of the amount of water that entered the attic for the open-soffit case at the wind speed of 70 mph (31.3 m/s). A quartering wind of 50 mph (22.4 m/s) produced very little accumulation of water in the attic. The amount was about 2.5% of the water entering during the same test for the open-soffit case.

Regardless of wind speed, water entry through the gable end vent was nearly equal

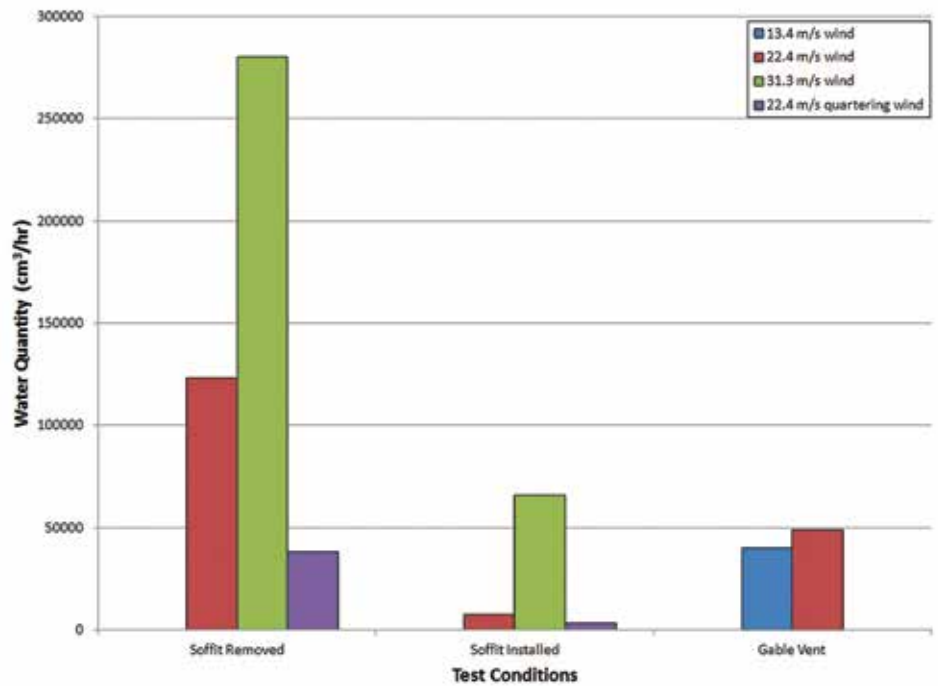


Figure 4 – Total amount of water entry into the attic per hour for under-eave and gable end conditions.

to the wind-driven water deposition rate based on the area of the vent. There was a slight indication of less water entry for high-

er wind speeds, but this difference could have resulted from water that was blown further into the attic in an area around the

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attic access stairs where collection pans were not in place.

A graph comparing the volume of water collected through the gable and soffit eave openings is shown in *Figure 4*. Note the difference between water entry through the soffit when installed versus removed. Water entry through the open soffit was several times higher than that with the soffit cover installed, demonstrating the importance of keeping the soffit material intact during high-wind events. Water entry through the eave (soffit material installed or removed) more than doubled when the wind speed was increased from 50 to 70 mph (22.4 to 31.3 m/s). Water entry through the gable end vent was not as affected by wind speed. Although the 70-mph (31.3-m/s) condition was not tested for gable end vents, the amount of water entry measured at the 30- and 50-mph (13.4- and 22.4-m/s) wind speeds was similar; and in each case, most of the water impacting the vent entered the attic.

SUMMARY AND CONCLUSIONS

These initial tests demonstrated that wind-driven rain will enter through open soffits and gable end vents. Installation of soffit materials using appropriate techniques, which reduce the chance of detachment during high-wind events, will therefore reduce the amount of water that enters attic spaces. Almost all wind-driven rain that impacts the gable end vent will enter the attic. In this case, the total amount of water that enters the attic will be a function of the size of the vent. Covering the vent prior to hurricanes and other high-wind events where rain is likely will reduce water entry into the attic. Using alternate venting systems that don't utilize gable end vents is also an option during new construction or reroofing. As a preliminary study, this work suggests more investigation is needed to quantify the amount of water entry that can be expected for normal construction and how much water entry is likely to be reduced with various water-entry prevention measures. 

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Ann Cope, PE, PhD

Dr. Anne Cope, PE, joined IBHS in 2009, having previously worked at Reynolds, Smith & Hills, Inc., where she served as a project manager and structural engineer in support of NASA, the Department of Defense, and commercial launch operations. As vice president of research at IBHS's new multiperil research facility in Richburg, SC, she is responsible for developing and guiding the research program. Her previous research has encompassed topics ranging from the simulation of full-scale wind effects on buildings to detailed studies of the vulnerabilities of buildings to natural hazards and the development of damage-prediction models. Cope's experience also includes time served as an officer in the U.S. Army. She earned her BS and MA in civil engineering from Clemson University and her PhD from the University of Florida. She is a registered professional engineer in the state of Florida.



Tanya M. Brown, PhD



Dr. Tanya Brown joined IBHS in August 2010 as a research engineer. Her research focus is on hailstone formation, hail impact testing, wind-flow characterization and testing, instrumentation, and field and damage assessment studies. Brown previously served as an engineering consultant for IBHS when she conducted research on the Witch Creek wildfire and development of the hail research agenda for the Research Center. She has also worked as an engineering consultant for LNSS & Associates. She was a National Science Foundation – Integrative Graduate Education Training Fellow

while completing her PhD in wind science and engineering at Texas Tech University. Brown also holds an MS in water resources science and a BS in atmospheric science from the University of Kansas. She is currently a faculty associate at Texas Tech and continues serving with the Texas Tech University Hurricane Research Team.

Stephen Quarles, PhD

Dr. Stephen Quarles joined the IBHS Research Center team in 2011 as the senior scientist for hurricane and high-wind building durability and fire protection. He is the S.C. High Wind and Hail Underwriting Association chair at the lab. Prior to joining IBHS, he retired from the University of California as a cooperative extension advisor in addressing the durability and in-service performance issues of wood-frame buildings, particularly those subjected to wildfires. He originally joined the university in 1985 and was made cooperative extension advisor in 2000. During 2007 and 2008, Steve also worked part-time with the California office of the state fire marshal, during which he developed, coordinated, and served as an instructor for the educational program related to the Wildland-Urban Interface (wildfire) Building Code and Standards. Quarles is a member of the Society of Wood Science and Technology board of directors, the American Society of Testing and Materials, the American Wood Protection Association, the National Fire Protection Association, and the Association of Natural Resource Extension Professionals. He earned a BS in forestry from Virginia Tech and MS and PhD degrees in forest products from the University of Minnesota.

