Assessing the Need to Modernize Water Penetration Resistance Test Procedures

Prepared by the Engineering School of Sustainable
Infrastructure & Environment at the University of Florida:

Ryan A. Catarelli, Ph.D.
Research Assistant Scientist and Principal Investigator

Brian M. Phillips, Ph.D.
Associate Professor

Forrest J. Masters, Ph.D.
Professor and Associate Dean for Research and Facilities

with support from the

Fenestration and Glazing Industry Alliance (FGIA; previously known as the American Architectural Manufacturers Association, AAMA), Window and Door Manufacturers Association (WDMA) and the Fenestration Manufacturers Association (FMA)

May 2, 2022

Introduction

This proposal is to study existing static and dynamic (i.e., cyclic) water penetration test procedures for building envelope systems to assess the need for modernization of procedures used for product approval. Current procedures (e.g., TAS 202, ASTM E 331 (2016), ASTM E1105, ASTM E2128, ASTM E 547 (2016)) apply enveloped pressure and wetting conditions to conservatively simulate hurricane wind and wind-driven rain (WDR) effects. While they serve as a good first approximator for evaluating product performance, these procedures have not benefited from advances in scientific knowledge and technology that have occurred over the last several decades (i.e., since their creation). Some knowledge considerations include:

- Steady pressure/wetting conditions are not physically realizable in a hurricane. Turbulence in the upwind flow and the flow distortion around the building cause significant spatiotemporal variation in pressure acting on the building surface. Only applying a steady "worst case" load fails to simulate the "lulls" that promote drainage – a principal design consideration for product manufacturers
- Cyclic pressure test procedures allow for lulls that promote drainage but are not representative of real-world rates of pressure fluctuation
- A major but easily addressable knowledge gap continues to perpetuate debate on the wind load intensity definition, e.g., 15% or 20% of the design pressure for fenestration in water infiltration tests
- The basis for the current minimum wetting rate (i.e., 5.0 gph/sf) originates from trial-and-error testing to determine the threshold required to cause uniform sheeting of water on a

curtain wall. It does not consider key factors such as climatology (addressed by the FY22 UF-Cornell project prioritized by the Hurricane Research Advisory Committee (HRAC) and funded by the Florida Building Commission), approach wind speed, location on the building, etc.

- Defining "failure" as a single drop passing into the building interior is not a representative measure of water damage, as the unmanaged accumulation of water over an entire hurricane episode is the principal driver for damage to walls, interiors, and building contents.

The project will (a) assess the role of each factor in codes/standards development and (b) invite industry and code officials to participate in experimental research using low-cost and straightforward-to-use technologies to compare "simplified" and "real-world" water penetration resistance testing. The latter will also enable the Florida Building Commission (FBC) and industry to better respond to issues raised following hurricane disasters, as these same systems can replicate the passage of the actual storm in question. The investigators may also produce guidance regarding the implementation of improved standard testing procedures, field testing, and certification.

Research Approach

The University of Florida will serve as the project manager, leading the project, in cooperation with a stakeholder advisory group that will guide this work.

This research proposes to apply methodologies built on prior work (Kopp et al., 2010; Lopez et al., 2011) to simulate hurricane-like wind pressure loading events for application on building envelope systems. Measured full-scale full-duration hurricane surface pressure sequences on building exterior wall surfaces are not readily available, thus a fluctuating applied pressure sequence will be synthesized from available data as follows:

1) Wind speed records will be derived empirically from historical hurricane track and intensity records from intense hurricanes representative of a design level event, e.g., Andrew (1992), Charley (2004), Harvey (2017), and Michael (2018).
2) Fluctuating surface pressure coefficient records will be extracted from boundary layer wind tunnel modeling of low-rise buildings. Many wind directions may be considered to determine a representative worst-case mean pressure time history tap location for a worst-case marine and/or open exposure.
3) The model-scale pressure coefficient record will be converted to an equivalent full-scale dynamic pressure.
4) Similarly, the velocity-dependent wetting rates will be derived from available sources, e.g., climatological studies such as the UF-Cornell study currently underway, satellite and radar-based measurements, etc.

The time-varying load sequence will be applied to building envelope systems using the closed-loop control system of the University of Florida's High Airflow Pressure Loading Actuator (HAPLA), which can test the water penetration resistance of a wide range of building systems. Water will be applied to the specimen surface using a rain rack system mounted inside the test chamber and calibrated to approximate field measurements of WDR intensities using the equation described in ISO 15927-3 (2009). Water infiltration will be measured using a high-resolution scale and water collection system to detect water quantities ranging from single droplets to gallons of flow per minute. Structural displacements may be measured using a set of laser displacement sensors targeted at points of interest on each specimen.

In addition to studying the performance of building components and cladding in “real-world” conditions, it is anticipated that the research design will include:

- Standard static and cyclic testing to produce a baseline for comparison
- Pressure sine sweeps to determine the (amplitude-dependent) threshold frequency at which applied pressure fluctuations no longer affect the flow through the building envelope.
- Application of extreme wetting rates to determine if a maximum upper bound for wetting exists for conventional building systems (it is hypothesized that an asymptotic limit exists for the rate of water ingress).

Anticipated Deliverables

1) Formation of a stakeholder advisory group to guide the research program, which will meet regularly to provide input on the research design, execution, and interpretation of results.

2) Results and analyses of threshold tests exploring the sensitivity of water ingress to the pressure frequency content and wetting rates.

3) Results and analyses of tests that compare steady and cyclic pressure/wetting conditions to “real-world” conditions. “Real-world” conditions include turbulence in the upwind flow and the flow distortion around the building that cause significant spatiotemporal variation in pressure acting on the building surface. These tests will shed light on the validity of existing test procedures.

4) Results and analyses of static and fluctuating pressure/wetting tests that address uncertainties regarding the standard 15% and 20% design pressure requirement for fenestration wetting tests. This will include assessments of the water ingress due to fluctuating pressure. Water ingress will be assessed in terms of accumulation during a testing event.

5) Results and analyses of tests conducted to assess the extent of unmanaged water accumulation via ingress over an entire hurricane episode. This will help determine the amount of water damage to be expected for products that may currently pass the standard test procedures. These findings could then be compared to field observations.

6) Guidance regarding the implementation of improved standard testing procedures based on results from anticipated deliverables 2-5.

7) Insight on how to correlate current testing procedures to potential new methods of testing that may be proposed as a result of the learnings achieved from the research.

Preliminary Budget Estimate

The budget for the work described above is estimated to range from $90,000 to $120,000.

References

ASTM E331-00 (2016) Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference.

ASTM E547-00 (2016) Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference.

ASTM E1105-15 (2016) Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference.

ASTM E2128-20 (2020) Standard Guide for Evaluating Water Leakage of Building Walls.

TAS 202-94 (2007) Criteria for Testing Impact and Nonimpact Resistant Building Envelope Components Using Uniform Static Air Pressure Loading.

ISO 15927-3 (2009) Hygrothermal Performance of Buildings–Calculation and Presentation of Climatic Data–Part 3: Calculation of a Driving Rain Index for Vertical Surfaces from Hourly Wind and Rain Data.

Kopp, G. A., Morrison, M. J., Gavanski, E., Henderson, D. J., & Hong, H. P. (2010). “Three little pigs” project: hurricane risk mitigation by integrated wind tunnel and full-scale laboratory tests. *Natural Hazards Review*, 11(4), 151-161.

Lopez, C., Masters, F. J., & Bolton, S. (2011). Water penetration resistance of residential window and wall systems subjected to steady and unsteady wind loading. *Building and Environment*, 46(7), 1329-1342.