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Water penetration resistance of residential window and wall systems subjected to steady and unsteady wind loading

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ABSTRACT

This paper presents results from two interrelated studies that investigated the performance of residential window and wall systems subjected to (1) simplified load scenarios and (2) realistic, time-varying load conditions. The first project investigated the diagnostic ability of standard water penetration test methods for the evaluation of residential systems. Static and rapidly pulsed pressure test protocols were compared using 2.4 m × 2.4 m wall sections with integrated windows. The second project quantified water ingress rates of operable, sliding seal windows under time-varying wind loads derived from wind tunnel measurements. The findings of this research indicated that the application of a static air pressure differential across the specimen is a practical, effective technique to evaluate watertightness of residential windows, however enhancements to the testing approach are warranted if systems level performance is to be evaluated.

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1. Introduction

In the last two decades, Atlantic hurricanes have caused more than $113 billion (2009 dollars) in insured losses [1]. Post-storm investigations conducted by FEMA [2,3], NIST [4], and others [5–7] have found that building envelope failures are the leading cause of wind damage. A critical, recurring problem in residential construction is unmanaged water ingress [8–10], which can damage or destroy the building's interior and its contents.

Related research has primarily focused on the modeling of wind-driven rain deposition on building façades [11–15], hygrothermal performance and drying [16–18], and to a lesser extent, fragility modeling [19]. Experimental findings are largely based on physical testing using a combination of simulated rain (using a spray rack) and application of steady, uniform loads on wood frame and masonry wall systems [20] and fenestration [8,21–24]. Only a few experiments have implemented realistic wind action on a building [25–29,55], which fluctuates due to the turbulence in the approach flow and the flow distortion caused by the building interacting with the boundary layer.

This paper contributes to the knowledge base by comparing the performance of residential window and wall systems subjected to (1) simplified load scenarios and (2) realistic, time-varying load conditions. The results of two interrelated experimental projects are presented. The first project investigated the water penetration resistance of residential wall systems with integrated windows (Section 4). It prompted a second research project to quantify water ingress rates of operable, sliding seal windows under time-varying wind loads derived from wind tunnel measurements (Section 5). This experiment was carried out to develop a conservative baseline for performance that can be directly related to the pass/fail criteria in modern water penetration standards.

2. Fenestration water penetration resistance requirements

In North America, the fenestration industry standard AAMA/WDMA/CSA 101/I.S.2/A440-05 [30] specifies that the minimum water penetration resistance of windows for residential and light commercial buildings shall be 15% of the structural design pressure (henceforth referred to as DP), which is determined from the wind load provisions in ASCE 7 [31]. For example, a window rated for a 1.4 kPa (30 psf) structural load is expected to prevent water ingress when a uniform static pressure is applied at 0.2 kPa (4.5 psf).

A common misconception is that this percentage is equivalent to the degree of water penetration resistance, i.e. 100% watertightness implies water holdout at 100% of the DP. This is generally not the case, owing to the unsteady nature of wind loading and the system response characteristics of the fenestration. In ASCE 7, the DP is computed from the external pressure coefficient (GC_p) for components and cladding. For small areas (<0.9 m^2), the GC_p value is

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