Water Entry Response of Wall Assemblies to Dynamic Driving Rain Wind Pressure

Zhe Xiao[ab], Michael A. Lacasse[a] and Elena Dragomirescu[b]

a National Research Council Canada, Construction Research Centre, 1200 Montreal Road, Ottawa, Ontario, Canada
b University of Ottawa, Ottawa, Ontario, Canada

Abstract

The pressure difference across a wall assembly arising from the Driving-Rain Wind Pressure (DRWP) produces a driving force that induces water ingress into wall assemblies given the presence of deficiencies on the exterior surface of the wall, and the downward migration of rain water over the wall surface. The extent of water penetration, which has a detrimental effect on the long-term performance of wall assemblies, is affected by the magnitude of the DRWP acting across the wall. In this study, a wall test specimen consists of 3 layers of polycarbonate sheathing has been tested under simulated Wind-Driven Rain (WDR) conditions. Deficiencies of different sizes and configurations were purposely built to the test specimen to investigate the extent of water entry given different DRWPs. To permit investigating the response of water entry under different DRWP conditions, a test protocol having a low cyclic rate was developed such that the water entry rates through the wall deficiencies could be obtained at different magnitudes of DRWP and as well, a variety of cyclic frequencies and amplitudes.

Peer-review under the responsibility of the organizing committee of the ICMB21.

Keywords: Wind-Driven Rain; Driving-Rain Wind Pressure; Watertightness Test; Wall Assembly

1. Introduction

An essential component to correlating WDR loads on wall assemblies to the moisture loads acting within the wall, is that of conducting watertightness test whereby the rate of water entry is determined in relation to the WDR loads acting on the wall [1-2]. Although it has been suggested in the ASHRAE standard [3] that a 1% ratio between the WDR and moisture loads be used in undertaking the performance assessment of wall assemblies, the results of experimental studies have proven that this requirement is inaccurate [4-5]. The DRWP is an equally important factor as the WDR intensity when determining the extent of water entry to wall. The work described in this paper refers to a wall assembly test specimen consisting of 3 layers of polycarbonate sheathing. The test specimen was subjected to simulated WDR and DRWP conditions. Cyclic pressure fluctuations were used with different magnitudes, frequencies, and amplitudes. The results obtained from these tests have been analyzed and are discussed to reveal the effect of different assembly characteristics to the water entry rate when subjected to varying DRWP loads under a uniform water spray rate to the exterior surface of the wall.

2. Testing Specimen

The test specimen for this study was 2.44m wide and 2.44m high and it was divided into six individual sections. Each section was also divided into three identical sub-sections. The infiltrated water in each sub-section was collected separately. Results from the three identical sub-sections were summed to obtain the total water ingress for one section. Three layers of polycarbonate sheathing were used to fabricate the specimen and represented, respectively, the exterior cladding, exterior sheathing board and air barrier of a wall assembly, this arrangement being typical of that found in wall assemblies following North American construction practice. Water collection was implemented in both cavities, that is, the cavity behind the cladding and that between the sheathing and air barrier panels. Three depths wall of cavity located behind the cladding were considered for each of the three sub-sections: 1mm, 5mm and 10mm.

Deficiencies were located at through-wall components that included a ventilation duct and cover plate. The ventilation duct had a diameter of 100mm and the spare cover plate a length of 150mm. As shown in Figure 1.a, the ventilation duct was installed in the opening passing through the cladding and sheathing panel layers. A cover plate was sealed to the ventilation duct on the exterior surface of the wall assembly. The gap between the ventilation duct and sheathing panel was filled with a backer rod and sealed using a silicone sealant. The sealant bead located along the top side of the plate was intentionally removed to simulate a deficiency; this consisted of a 50 mm long portion of sealant. This same deficiency was also created between the ventilation duct and sheathing panel. An 8mm thick horizontal joint opening was made in the cladding and sheathing board for the in-plane (joint) deficiency (Figure 1.b). The length of the in-plane (joint) deficiencies on each sub-section were identical.

 DOI: 10.14293/ICMB210068

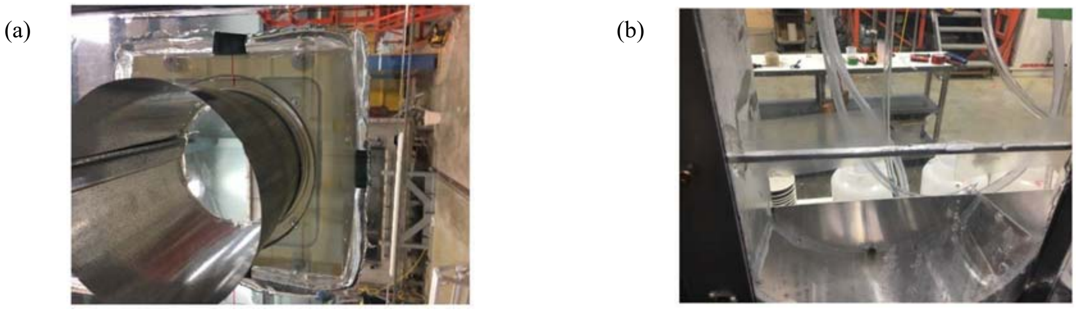

Figure 1. (a) Through-wall deficiency; (b) In-plane (joint) deficiency

3. Results and Discussion

Figure 2.a permits demonstrating the water entry rate at each pressure frequency for the respective deficiency types and different cavity depths. For the in-plane (joint) deficiency, the 10mm cavity had the highest water entry rate, whereas the 5mm cavity had the lowest rate of water entry at all three pressure frequencies. For the 10mm cavity wall assembly the variation of pressure frequency had the smallest effect on the water entry rate. Whereas for the wall having a 5mm cavity depth, higher values of pressure frequency led to higher water entry rates. The highest water entry rate for the 1 mm cavity section occurred at a pressure frequency of 4 cycles/min. In regards to the through-wall deficiency, the pressure frequency fluctuation only had a very slight effect on the water entry rate for all three cavity depths.

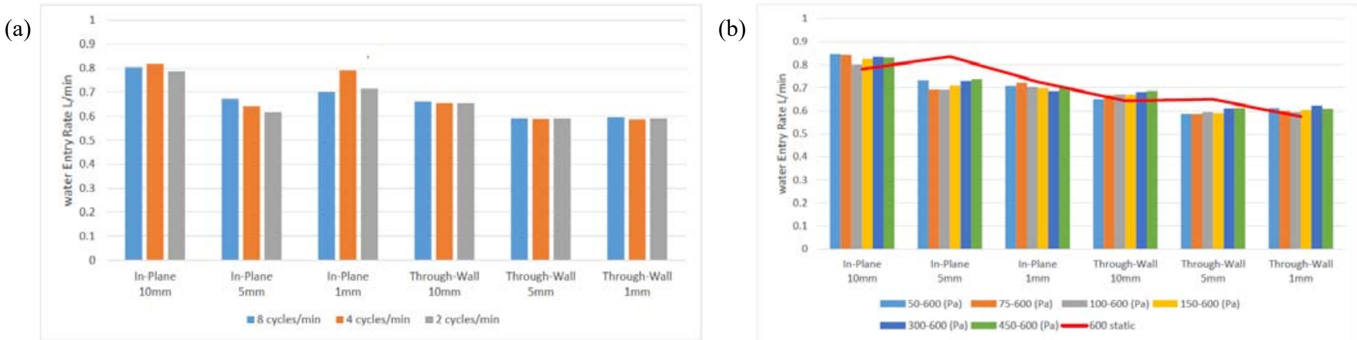

Figure 2. (a) Water entry rate for different pressure frequencies; (b) Water entry rate for dynamic pressure

In Figure 2.b, the water entry rates for investigated dynamic pressure steps at different lower limits were similar to each other. The discrepancies are mainly due to the types of deficiency and depths of cavity. In-plane (joint) deficiencies have a greater amount of water ingress, as compared to through-wall deficiencies and more water was collected from cavities of greater depth, as compared to the amounts collected in cavities of smaller depth. For cavity sections of 5mm depth, the water entry rate obtained at a static pressure of 600 Pa was greater than that for the dynamic pressure step for both deficiencies. Whereas water entry rates obtained from the static pressure were similar to that measured from dynamic pressure steps for the remaining sections.

Discrepancies as arose were induced by variations of the frequencies and amplitudes of DRWPs used in this study. However, such differences were relatively small when compared to the overall rates of water entry. This suggests that neither the frequency nor amplitude of DRWPs need to be considered as dominant factors in a watertightness test. In a parallel and subsequent study focused on the development of a watertightness test protocol, a 0.1 Hz frequency was selected from the power spectrum of the wind velocity [6], and where it is evident that the wind energy level drops dramatically. In addition, 20% of the overall pressure value was used as the amplitude of different tests levels for the dynamic DRWP tests.

References

[1] M. Rousseau, *An overview of the survey of building envelope failures in the coastal climate of British Columbia*, performed by Morrisson-Hershfield Limited for CMHC (1996), J. Therm. Envelope Build. Sci. 22 (4) (1999) 364–367.

[2] A.O. Desjarlais, A.N. Karagiozis, M. Aoki-Kramer, *Wall moisture problems in Seattle*, in: Proc of the Thermal Performance of the Exterior Envelopes of Whole Buildings VIII Proceedings, 2001, p. 8

[3] A. TenWolde, "*ASHRAE standard 160P-criteria for moisture control design analysis in buildings*", 2008.

[4] Sahal N., Lacasse M. A. (2004), "*Experimental Assessment of Water Penetration and Entry into Siding-Clad Wall Specimen*", Internal Report (National Research Council of Canada. Institute for Research in Construction); No. IRC-IR-862; Ottawa, Canada, 58 p; doi.org/10.4224/20377802.

[5] Sahal N., Lacasse M. A. (2005), "*Water entry function of a hardboard siding-clad wood stud wall*", Proceeding of the 10DBMC International Conference on Durability of Building Materials and Components, April 17, 2005, Lyon, France, 9 p.

[6] H. W. Teunissen (1970), "*Characteristics of the Mean Wind and Turbulence in the Planetary Boundary Layer*", Institute for Aerospace Studies, University of Toronto.