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RAINWATER INGRESS THROUGH RESIDENTIAL SLIDING WINDOWS

Korah Parackal, John Ginger, Alexis Leblais, David Henderson
James Cook University, Bushfire and Natural Hazards CRC

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INTRODUCTION

Damage investigations carried out following windstorms have shown significant damage caused by rainwater ingress (Boughton, Falck et al. 2017). A preliminary experimental study was carried out at the Cyclone Testing Station (CTS) that simulated wind driven rain on a residential window under strong wind conditions to observe rainwater ingress.

The external pressures on a building envelope vary in time and space on the surface of a building with windward walls experiencing positive pressures and all other surfaces (side and leeward walls and roof) subjected to negative pressures.

Internal pressure fluctuations in a nominally sealed building with a porous envelope, are generally much lower than the external pressure fluctuations. This internal pressure is usually a small suction pressure and hence the net (i.e. (external – internal)) pressure across the windward wall is positive but negative across the other surfaces. This pressure differential along with wind driven rain can result in air-entrained water ingress into the building through windows that are closed due to gaps and weep-holes.

Preliminary tests were conducted at the CTS on a window attached to the wind driven rain simulator (WDRS) to assess rainwater leakage and potential measures that could reduce leakage.

EXPERIMENTAL SET-UP

A wind driven rain simulator (WDRS) was constructed at the CTS. The WDRS is an open face air-pressure-chamber equipped with two ‘spray bars’ to simulate rain and is connected to a Pressure Loading Actuator (PLA) to simulate the net pressure on the window. The spray bars were made of PVC pipes and attached to water sprinklers orientated towards the open face of the air-pressure-chamber. The spray bars were connected to the water supply through a flow valve and flow meter to control the water flow rate.

A stud wall with a residential sliding window was attached to the open face of the air- pressure-chamber to simulate ‘real-life’ conditions for the window, as shown in Figure 1. A single glass sliding window comprising of one fixed glass panel and one slider glass panel was tested in this study. The overall window size was approximately 1 m × 1 m hence the surface area of the window was approximately 1 m2. The window was specified as C2 cyclone rated. The window was set up in the WDRS with its outdoor side facing the inside of the WDRS. This simulates ‘real life’ conditions since the rain and pressure are applied inside the chamber of the WDRS. A ‘water-collecting tray’ was fixed under the windowsill to collect water leaking through the window during the tests.

FIGURE 1. WDRS WITH WALL AND WINDOW TEST SAMPLE

Windstorms events are complex and many variable factors affect the strength of the event and its effects on buildings. These variables are difficult to measure accurately and difficult to accurately simulate. The following assumptions and approximations were made in this study:

- The sizes of the raindrops were not adjustable nor were they evaluated.
- The water was sprayed directly and constantly in the direction of the window.
- The water flow rate impacting the window was fixed at approximately 3 L/m2.min. This value was chosen to be on par with recommendations in AS4420.1 (no less than 3 L/m2.min) and ASTM E331-00 (no less than

3.4 L/m2.min).

- The visual effect of the sprayed water on the window was qualitatively similar to the rain impacting a window during a strong windstorm. The water flow rate impacting the window, can be about 10 times less than those intense short rainfalls, lasting 1 minute (31.2 L/m2.min recorded in Maryland in 1956 according to Lopez (2009)).

TEST CONFIGURATIONS

The aim of this study was to assess the water ingress through a residential window under strong wind conditions, and to find ways of mitigating this water ingress. The configurations described in Table were studied.

TABLE 1. LIST OF CONFIGURATIONS

Configuration	Description
C1	Standard window, no modification
C2	Blu-tack and tape over outside weep holes
C3	C2 + Tape over track weep holes and blu tack in corner of slider
C4	Three thicknesses of tape in track
C5	C2 + tape at joint glass/frame
C6	C5 + tape at joint slider/frame
C7	C3 + tape at joint glass/frame
C8	C7 + tape at joint slider/frame
C9	Plastic taped over the bottom of the window

TEST PLAN

Two type of tests were conducted in this study, static pressure tests and fluctuating pressure tests. The static tests were aimed at assessing the water ingress through the window as a function of the net pressure across the outdoor and indoor sides of the window. The fluctuating tests were aimed at representing an actual windstorm on the window,and assessing the water ingress as a function of the configurations in Table1.

STATIC PRESSURE TESTS

For the static tests, only configurations C1 and C8 were evaluated to compare a set up with no modifications versus a set up with the maximum amount of tape and blu-tack, expected to provide the best protection against water ingress.

For each test the water was turned on first for 30 seconds to allow the flow rate to settle and create constant rain conditions inside the WDRS. The desired pressure was then selected and the PLA turned on for 2 minutes to simulate the net pressure differential. After the 2 minutes the PLA was turned off and finally the water was turned off. For each test, the water that leaked through the window was collected in the tray and the volume of water collected was recorded.

FLUCTUATING PRESSURE TESTS

For the fluctuating tests, the PLA was run in automatic mode, allowing for dynamic pressure traces to be applied. Two dynamic traces were used, both generated from a wind tunnel study determining the pressure fluctuations on a windward wall of a building. The dynamic traces were scaled in intensity to allow for their peaks to reach 800 Pa and 1200 Pa respectively. Both traces run for approximately 2 minutes and 45 seconds. Figures 2 and 3 show the dynamic traces as a function of time with peaks at 800 Pa and 1200 Pa respectively.

For each test the water was turned on first for 30 seconds to allow the flow rate to settle and create constant rain conditions inside the WDRS. The desired trace was then selected and the PLA turned on to generate the pressure trace. After completion of the trace run the PLA was turned off and finally the water was turned off. For each test, the water that leaked through the window was collected in the tray and the volume of water collected was recorded.

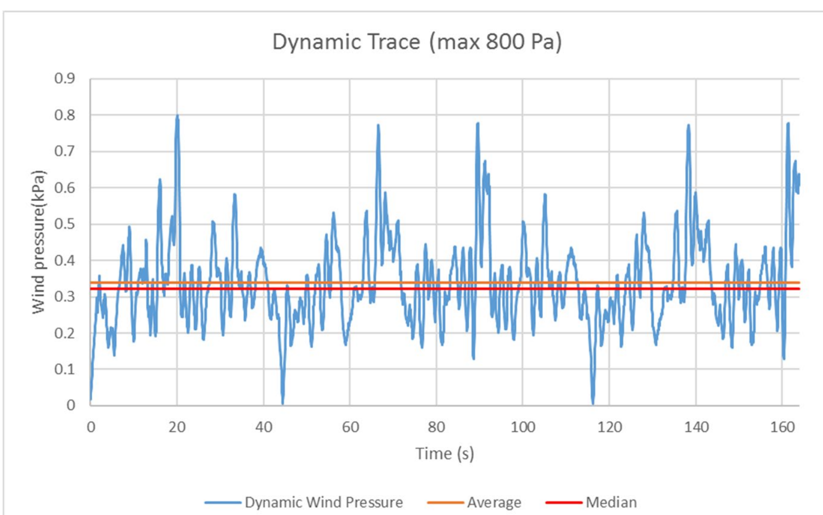

FIGURE 2. DYNAMIC TRACE WITH MAXIMUM 800 PA PRESSURE

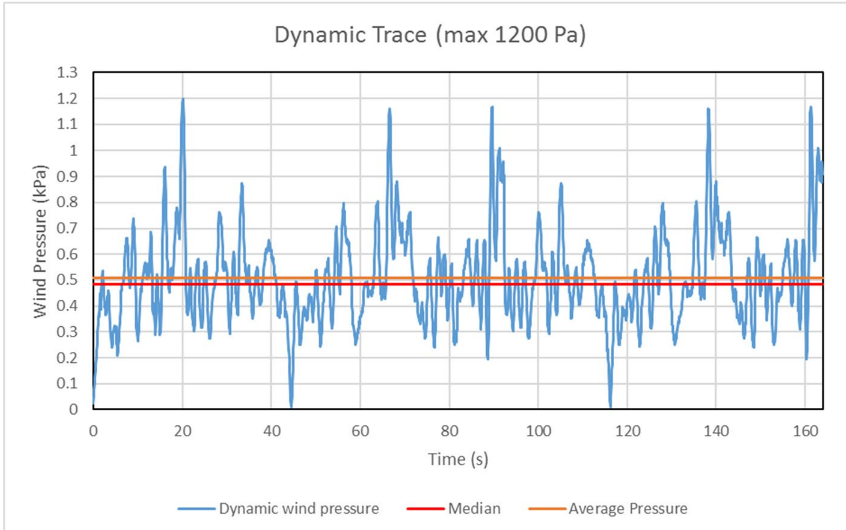

FIGURE 3. DYNAMIC TRACE WITH MAXIMUM 1200 PA PRESSURE

RESULTS

STATIC PRESSURE TESTS

The water ingress through the window as a function of the net pressure differential between the outdoor in indoor sides of the window for configurations C1 and C8 is shown in Figure 4.

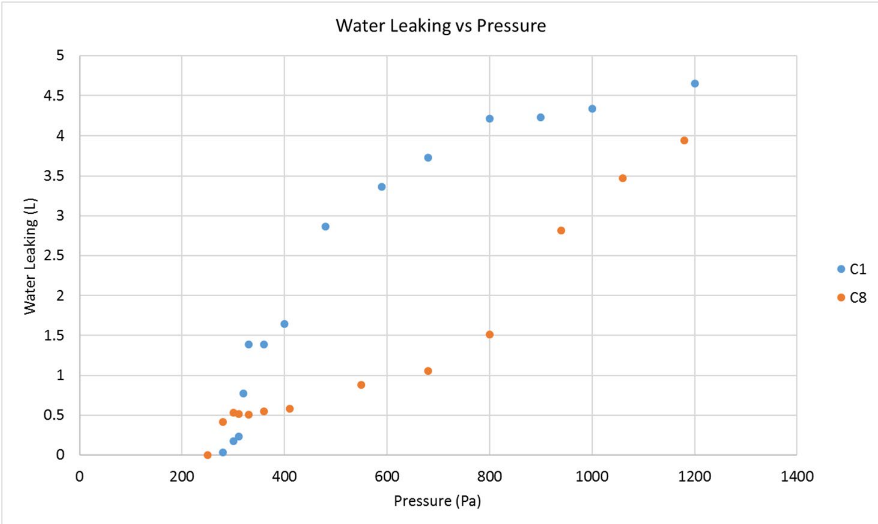

FIGURE 4. WATER INGRESS AS A FUNCTION OF STATIC PRESSURE

The results of the static tests show that obstructing the possible water pathways in the window with tape and blu-tack can reduce the amount of water ingress, mainly when the net pressure differential between the outdoor in indoor sides are between 400 Pa and 1000 Pa. However, it must be noted that blocking the window's weep holes prevents the water accumulated in the track from returning to the outdoor side. This contributed to the water ingress being higher for the C8 configuration than the C1 configuration at less than 300 Pa. Since the water trapped in the track was not able to return to the outdoor side, it was collected and measured as water that had leaked through the window.

FLUCTUATING TEST RESULTS

The water ingress through the window for each configuration and pressure traces is given in Figure 5.

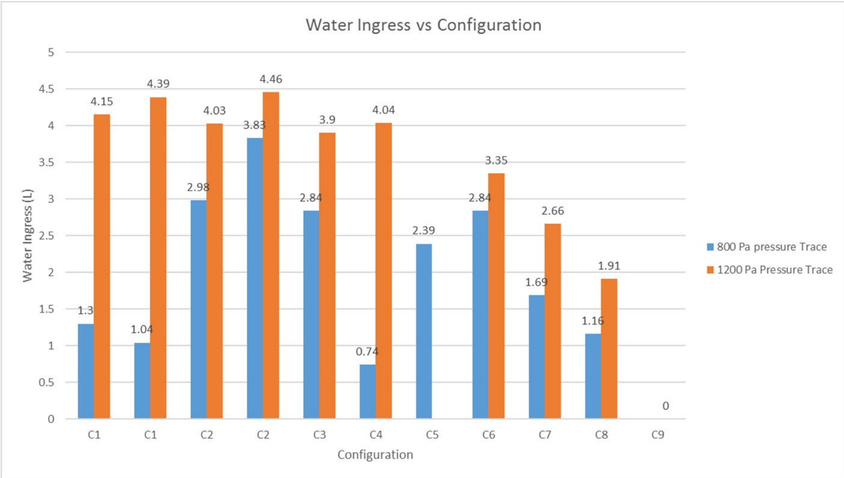

FIGURE 5. WATER INGRESS AS A FUNCTION OF CONFIGURATION

The results of the fluctuating tests show that the only effective method we found to prevent water ingress was by using the C9 configuration.

These tests also confirmed the observation previously made that blocking the weep holes could actually worsen the water ingress. This is particularly true for the less intense pressure peaks. It was observed that when the pressure decreased between the peaks, the amount of water in the window track reduced by leaving through the weep holes. Obstructing the weep holes therefore prevents this phenomenon and the track does not empty, contributing to increased water ingress. This observation is highlighted in configurations C1 and C4 with the 800 Pa trace. The amount of water ingress is significantly less than for all other configurations where the weep holes are obstructed.

However, obstructing water pathways as much as possible like in configuration C8 is effective to reduce the amount of ingress water at higher pressure (1200 Pa trace). This configuration saw a reduction of ingress water by about 50% in comparison with the C1 configuration and 1200 Pa trace. Although this is an interesting result to take into consideration for future studies, where the implementation of the C9 configuration might not be possible, it must be noted that setting up the C8 configuration is much more time consuming and tedious than the C9 configuration.

The only configuration that produced an insignificant amount of water ingress was C9. Figure 6 shows configurations C1 and C9 side by side during a pressure peak of the 1200 Pa dynamic trace. We can observe a significant amount of water leaking out of the window on the left side, while the water is constrained by the plastic lining on the right side. The amount of water that leaked through the tape and plastic of configuration C9 was so small that no water was able to reach the water collecting tray.

FIGURE 6. SIDE BY SIDE VIEWS OF CONFIGURATIONS C1 AND C9 DURING PRESSURE PEAK AT 1200 PA

CONCLUSIONS

Post disaster damage surveys have shown that damage to interior linings and home contents due to water ingress through such sliding windows are frequent causes of damage and loss of amenity for residents.

Water ingress through modern sliding windows often occurs through the window tracks. Gaps between panels and through weep-holes. Preliminary tests on water ingress through residential sliding windows were performed at the Cyclone Testing Station at James Cook University. Testing was conducted on several configurations that involved sealing gaps in the windows and weep-holes by increasing extents. None of these configurations were effective at reducing water penetration through the window under static and dynamic testing scenarios.

However, a final configuration of using a plastic sheet placed over the bottom of the window with the sides taped securely to the window frame was effective in holding water that did enter through the window. It is recommended that further testing be performe on other styles of windows and details and new, more water resistant detailing of windows designs be developed.

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