ICWE 16
August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering

Full-Scale Testing on Doors, Windows, Soffit, and Fascia using a Wireless Sensor Network System

S. Sridhar [1], J. Zhang [2], J. Wang [2], A. Lebbar [2], C.S. Subramanian [2], J-P. Pinelli[2], S. Lazarus [2]

[1]Florida Institute of Technology, Melbourne, USA, ssridhar2017@my.fit.edu
[2] Florida Institute of Technology, Melbourne, USA, hursensors@lists.fit.edu

SUMMARY:
Hurricanes and tropical storms can damage non-structural components such as windows and doors, leading to interior damages and losses. This paper focuses on experimental pressure data from the Wall of Wind facility, on different non-structural components such as doors, windows, soffits, and fascia during high wind speeds (27, 40, 54, 65 m/s). For this purpose, a full-scale test model called the “FIT house” was instrumented with a combination of wireless sensors in aerodynamic casings, and Scanivalve patches connected to wireless sensors. This research studies the pressure coefficients (C_p) on soffits, fascia, doors, and windows (with and without shutters) and compares the experimental C_p values to the ASCE 7-22 values. Preliminary experimental results show that i) Upon installation of shutters, the C_p values for the door only reduce in the range of 1 to 20 %, and for the window by 1 to 40 %, and ii) C_p of all components tested agree well with ASCE 7-22.

Keywords: Wall of Wind, Wireless Sensor Network System, components and cladding, ASCE 7-22.

1. EXPERIMENT TEST SETUP

The FIT house model was tested at the Wall of Wind facility of Florida International University (A.M.Aly, Chowdhury, & G.Bitsuamlak., 2011). It was a full-scale gable roof building with a door and a window (Fig.1). The cladding components that were tested include doors, windows, soffit, and fascia. The following sections describe their instrumentation.

1.1. Door and Window, With and Without Shutter

The doors and windows, as shown in Figure 1, of the FIT house were instrumented with Scanivalve patches hot glued to the surface, and their pressure tubes were connected to the pressure transducer of wireless sensor boards on the inside of the house. Wireless sensors in aerodynamic casings (J. Wang, et al., 2021) were also attached behind the door and the window using Dual Lock™ adhesives. Aluminium shutters were installed in the later part of the experiment, as shown in Figure 2.

The experiment was performed at different speeds of 27, 40, 54, 65 m/s, for wind directions ranging from 0° to 180° in steps of 22.5°. The pressure was sampled at 10 Hz for a period of 180 seconds, for every test.

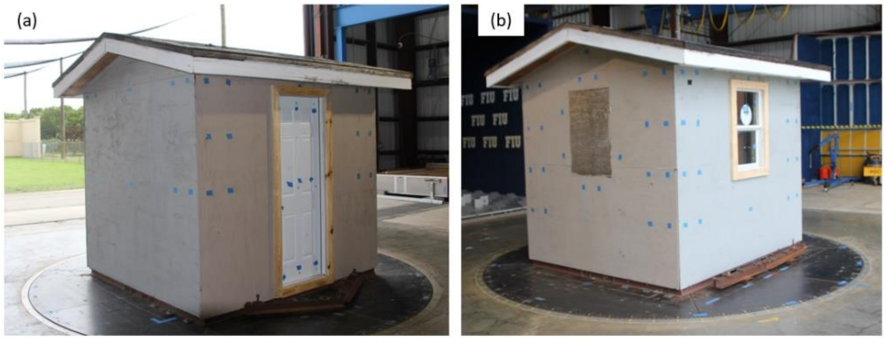

Figure 1. FIT house model with door (Right) and window (Left)

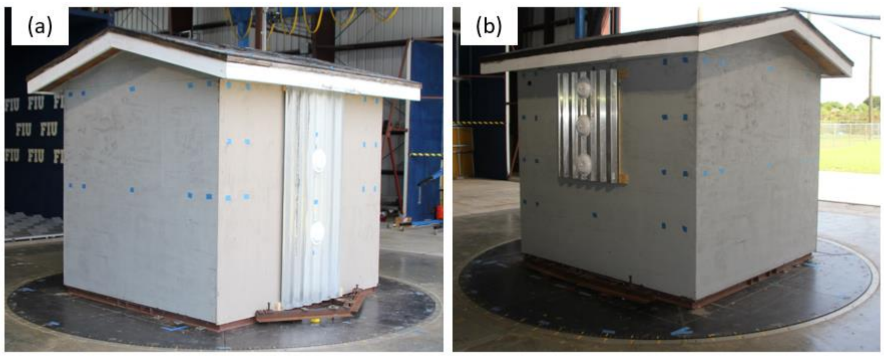

Figure 2. Aluminium shutters were installed to study the effect of shutters on doors(left), and windows (right).

2.2. Soffit and Fascia

Scanivalve pressure patches were hot glued to the fascia of the FIT house model, and wireless sensors with aerodynamic casings were attached to the soffit panels, as shown in Figure 3. The experiments were performed under similar test conditions as the ones described in Section 2.1, except for wind directions ranging from 0° to 337.5° in steps of 22.5°.

Figure 3. Scanivalve patches and wireless sensors attached to the soffit and fascia of the FIT house model.

3. EQUATIONS

External C_p values were computed to study the pressure distribution on different components during high-impact wind events. Data from the wireless sensor network system was uploaded to DesignSafe-CI (E.M. Rathje, et al., 2017) and is yet to be published. The measured absolute pressure values were converted to C_p time histories using Equation 1:

$$C_p = \frac{p-(p_{amb}+p_s)}{0.5 * \rho * v_\infty^2} \quad (1)$$

Where:

- p = absolute local pressure,
- p_{amb} = atmospheric pressure from Miami International Airport (MIA) weather station,
- p_s = static pressure difference from reference cobra probe,
- ρ = freestream (fs) fluid density of air, and
- v_∞ = fs velocity.

4. EXPERIMENTAL DATA ANALYSIS – PRESSURE CHARACTERISTICS

The mean pressure coefficients of the different components were computed as the average of C_p values from each test condition. The results show that the mean C_p on the door is nearly the same at any given speed and location. Figure 4 shows mean C_p values for the door and window, along with a sketch of sensor location and wind direction for reference. Shutters play a more effective role on windows than on doors as their C_p values drop by a range of 1% to 40%, compared to that of doors which drop by a range of 1% to 20% when shutters are installed. These results show smaller differences in C_p values without and with shutters when compared to a similar experiment performed on glass sliding doors (S. Sridhar, et al., 2022) that showed a drop of 40% to 60%.

The ASCE 7-22 (ASCE 7-22, 2022 Edition) suggests a combined gust effect factor and positive external pressure coefficients (GCp) for walls, ranging between 0.7 and 1 based on the effective wind area of the component. The window and door, defined as components of the wall have effective areas of 0.68 m^2 (7 ft^2) and 1.54 m^2 (17 ft^2) and the measured Cp values agree well with the ASCE 7 standards. The maximum negative C_p values for the window and door are -0.6 and -0.7, which also agree with the suggested ASCE 7 range from -0.8 to -1.0.

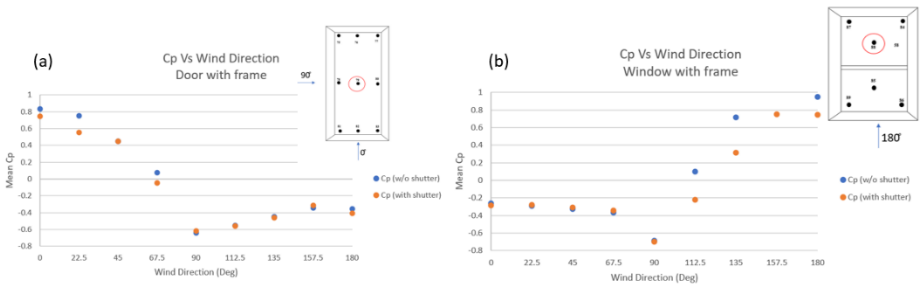

Figure 4. Mean computed Cp values for (a) Door, and (b) Window as a function of wind direction.

The Cp values from the sensors on the fascia boards parallel to the roof gable were identical to the measured internal Cp values. However, Cp values from the drip edge perpendicular to the roof gable were lower than the internal Cp value. Further analysis shall address the relationship between the maximum and minimum load with respect to location, on fascia panels.

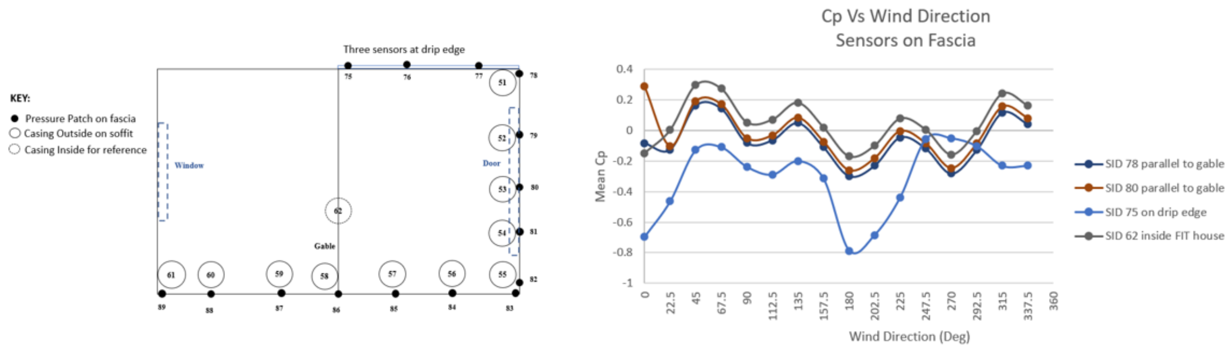

Figure 5. (Left) Sensor Locations, (Right) Cp plot for sensors on fascia.

The full paper will further analyze the 3-second peak pressure coefficients of different components and determine their relationship to locations and wind directions. Further analysis will also provide comprehensive and better comparisons to the ASCE 7-22.

ACKNOWLEDGEMENTS

We thank the National Institute of Standards and Technology for funding this work under grant 70NANB19H088. The National Science Foundation (NSF) also financially supports the data analysis in the DesignSafe-CI project under grants CMMI-1520817 and 2022469. We are immensely thankful to the FIU WOW team for sharing their cobra probe data and for letting us work with them to measure data from the FIT house model.

REFERENCES

A.M.Aly, Chowdhury, A., & G.Bitsuamlak. (2011). Wind Profile Management and Blockage Assessment for a New 12-Fan Wall of Wind Facility at FIU. *Wind and Structures*, 285-300.

ASCE 7-22, 2022 Edition, *2022 - Minimum Design Loads And Associated Criteria For Buildings And Other Structures*

E.M. Rathje, C. D.-P. (2017). DesignSafe: A New Cyber-infrastructure for Natural Hazards Engineering. (pp. doi: 10.1061/(ASCE)NH.1527-6996.0000246). ASCE Natural Hazards Review, Volume 18 Issue 3.

J. Wang, J. S.-P. (2021). Development of a Wireless Sensor Network for Hurricane Monitoring. *6th American Association for Wind Engineering Workshop.* Clemson, SC.

S. Sridhar, J. Z.-P. (2022). Measurement of Wind Loads on Glass Sliding Doors using a Wireless Sensor Network System. *14th Americas Conference on Wind Engineering.* Lubbock, Texas.