FIU Wall of Wind Test Report

Presented to:
Storm Stoppers
c/o John D. Smith

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Project summary

The following report describes the methodology followed and summarizes the results of a wind test to evaluate the performance of Storm Stoppers Original 3/8 inch Translucent Plastic Panels, herein known as "Storm Stoppers Panels", using Florida International University's Wall of Wind (WOW).

The WOW is an open-circuit wind tunnel that uses 12 electric fans, each capable of producing a maximum flow of 240,000 cfm. A detailed description of the WOW technical aspects is given on Appendix C to this report.

Test specimen description

Test Specimen

The subject of this testing is the Storm Stoppers Panels, which consist of 3/8 in. thick translucent plastic panels (known as the Original 3/8"). The panels are typically installed over doors and windows to protect them from strong winds and rain during hurricanes and strong storms. The test at FIU only evaluated performance for wind and wind-driven rain and not impact from debris. The Storm Stoppers Panels installed on windows and door were flush-mounted directly to the door and window frames with 3M® Dual Lock® Reclosable Fasteners.

The Storm Stoppers Panels were installed on four windows labeled W1, W2, W3 and W4 and one door labeled D1 as shown in Figure 1. The windows and door were installed on a model house as described in the following section. The test model or its performance under wind conditions are not part of the scope of this project and only provide a means to install the product of interest. The sizes of the window panels were: 26 in. (W) x 38 in. (H) x 3/8 in. (T). The door panel was 32 in. (W) x 81 in (H) x 3/8 in. (T) with cutouts for the doorknob and lock.

The panels were fastened using 3M® Dual Lock® Reclosable Fasteners in two different sizes: 1 in. x 1.5 in. (regular) and 0.5 in. x 1.5 in. (narrow). The spacing of the regular fasteners was 4.5 in. apart and 2.25 in. for the narrow fasteners. All surfaces were cleaned and primed prior to installation by Storm Stoppers representatives.

A Storm Stoppers representative installed the Storm Stoppers Panels per manufacturer installation instructions. Pictures of the panels and installation are shown in Appendix B.

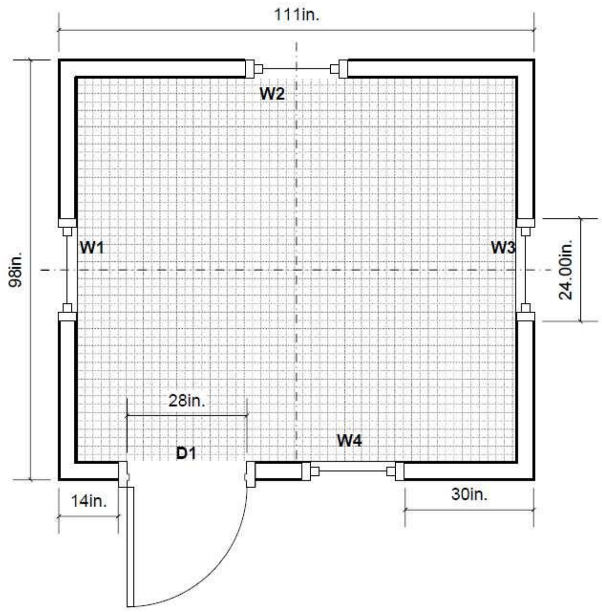


Figure 1 – Floor Plan: Location of door and windows protected with Storm Stoppers panels on base structure

Test Base Structure

The Storm Stoppers Panels were installed on four windows and one door of a pre-existing house model provided by FIU. The house model was selected after discussion with Storm Stoppers representative through emails and conference calls. The outside dimensions of the house's floor plan measured approximately 111 inches by 98 inches. Each wall had a 24 in. wide by 36 in. high impact-rated single-hung windows installed. One side had a 79 in. high by 28 in. wide prehung 1-panel exterior door installed as shown in Figure 1. It is not known if the door was impact rated.

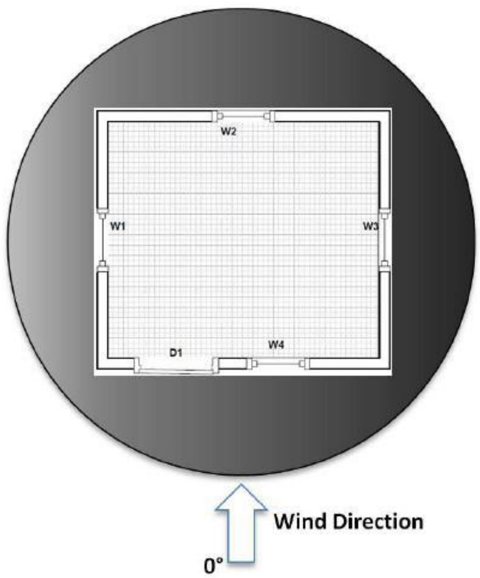
The house model that served as test base structure consisted of a wooden-frame house with exterior PVC siding and interior drywall board walls. The wall height was 7 ft. 4 in. The roof was a gable roof with 5:12 slope with 3-tab shingles. The walls and roof of the house model were constructed according to standard construction practices that are not necessarily representative of construction practices allowed in the High-Velocity-Hurricane-Zones (HVHZ) as described in the Florida Building Code (Chapter 2, Section R202, 2010 Florida Building Code Residential). The base structure was previously used for a different set of tests as disclosed to Storm Stoppers representatives during the initial discussions. The house had two holes on the roof from this previous test, which were repaired by FIU prior to the test as proposed.

The house model sat on a metal foundation framing that allowed it to be moved and repositioned on the turntable. This platform is not representative of typical foundations and exists to allow connection to FIU Wall of Wind turntable. The metal platform was anchored by 3/4-10 bolts to predetermined anchor points on the turntable along the perimeter and two 2 in. by 5 in. rectangular steel tubes that fit through the platform and work as clamp-downs.

Test method

The Scope of Work of this project was defined according to Storm Stoppers inventor John D. Smith. The objective of the test program was to acquire video material while evaluating the performance of the Storm Stoppers Panels during wind and simulated rain up to hurricane-force winds of about 130 mph at a height 5.5 ft or until failure if it occured at a lower speed. The testing methodology consisted of “blow-off testing” in which direct observations were made of wind speeds of the applied flow and the reaction (if any) from the panels. Wind induced movement or detachment would be noted and paired with the wind speed at which it occurred.

The test setup was tested through a sequence of increasing wind speeds initially at a wind angle perpendicular to the model’s surface (0 degrees as shown in Figure 2). Subsequent wind angles were to be considered as requested by Storm Stoppers representatives after completing a wind testing sequence.



HD Camera (left)
Set up by Storm
Stoppers

HD Camera (right)
Set up by Storm
Stoppers

Figure 2: Test structure at zero degree with door (D1) and window (W4) perpendicular to the wind.

The test started at a low speed (10 mph) and was held constant at each wind speed interval for a set period of time and sequentially increased in increments of 10 mph. The duration of the time intervals were set as requested by Storm Stoppers inventor John D. Smith. Observations (and low definition video recording) were made by FIU Wall of Wind staff for the duration of the test to identify movement or changes on the panel installation. The target speed was 130 mph but at around 120 mph the house model became detached from its foundation. The maximum wind speed measured during the test was 126.8 mph at 10.5 feet high. Simulated rain was applied together with the wind for the entirety of the test.

Instrumentation description

Tests were recorded with FIU surveillance quality video cameras at multiple angles. Storm Stoppers and/or their representatives recorded the tests using two high definition cameras at two angles upwind of the test structure (Figure 2).

The Wall of Wind calibrates the wind field using free-flow measurements and uses this information to set the target wind speeds. Wind calibration was done prior to testing of this project on 6/19/2014 using Cobra Probes at predetermined heights at the center of the turntable as shown in Appendix A, Table 1. These measurements were made to validate the boundary layer profile and wind speed at each throttle step.

Boundary Layer Profile

The Wall of Wind is a large-scale boundary layer wind tunnel. As such, it uses flow management to give characteristics to the flow that simulate realistic wind speed and turbulence conditions. The boundary layer profile simulated for these tests was equivalent to Open Terrain (Exposure C, as defined by ASCE7-10 Minimum Design Loads for Buildings and Other Structures, section 26.7.2). This surface roughness category includes flat open country, grasslands and shorelines in hurricane prone regions. (See Appendix A for more information).

Wind Speed

The wind speed was varying at set steps and durations, starting at 10 mph and up to 130 mph in 10 mph increments. The wind speed display used during testing measures average wind speed at a height of 10.5 ft. above the test section floor and does not account for blockage effects imposed by the model. The following graph shows the target intensity of the wind speed based on free-flow calibration and mid-height of the test specimens (door and windows) and the durations for each wind speed.

A reference wind speed display was used during testing to show actual measured wind speed at 10.5 ft. above the ground. The wind speed at 5.5 ft was based on open terrain exposure measurements and is given in Table 1.

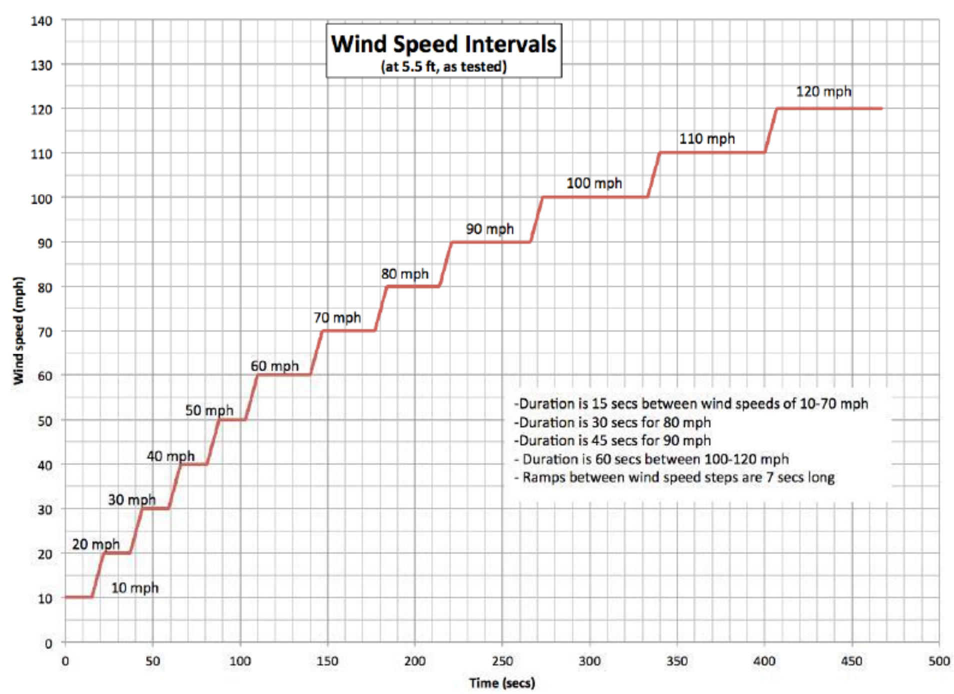


Figure 3 - Target wind speed intervals set for the test

Test Results

Observations

1. The Storm Stoppers Original 3/8 inch Panels installed on the door and windows of the base structure did not move nor become detached from its fasteners for the wind direction tested (0 degree) and up to the wind speed step of 120 mph at 5.5 ft. (corresponding to 126.8 mph at 10.5 ft. height above the test section floor).
2. The test was stopped during the wind speed of 120 mph (corresponding to 126.8 mph at 10.5 ft. height above floor) due to detachment of the connections between the test structure walls and the metal foundation.
3. No further observations about the performance of the panels are done after the house model became detached from its foundation platform and the test was stopped.

Limitations

1. The performance of the panels for the wind direction and conditions tested should not be extrapolated to other cases and wind angles not considered in this testing.
2. Results are based on specific panel size and installation conditions and are not representative of all installation applications.
3. The target wind speeds set for the test are not directly correlated to the Saffir-Simpson Hurricane Scale (SSHS) wind velocities. This is due to differences in the definition of the Saffir-Simpson Hurricane Scale to the definition of velocities for structural design purposes. The Wall of Wind simulated flows should be considered as equivalent to about 3-second gust intensities at the defined height on the boundary layer (in this case 5.5 ft. above the ground).

   SSHS wind velocities are defined by the National Hurricane Center as the maximum sustained surface wind speed (peak 1 –minute wind at the standard meteorological observation height of 33 ft. over unobstructed exposure). Unobstructed exposure is typically considered over open water and should not be confused with open terrain exposure. A gust wind speed differs from the peak 1-minute used on the SSHS and appropriate conversion methodologies must be applied to associate and compare the wind speed intensities as defined by each.

Appendix A – Wall of Wind wind characteristics

12-Fan Wall of Wind Boundary Layer Profiles

Setup: Open Terrain Spires, 9 inch Triangular Floor Roughness, 3.5 inch Cubic Floor Roughness
Measurements conducted on: 6/19/14
Free stream measurements location: center of turntable.

Table 1: Centerline average wind speed at center of turntable (See section labeled Wind Speed)

Mean Wind Speed:	mph	mph	mph	mph	mph	mph	mph	mph	mph
Height, z (ft) 10.5	8.0	23.6	32.0	48.0	64.0	80.6	96.9	113.0	128.7
5.5*	6.8	22.3	29.9	45.0	60.2	75.4	90.3	105.3	120.6

*Average height of installed Storm Stoppers Panels

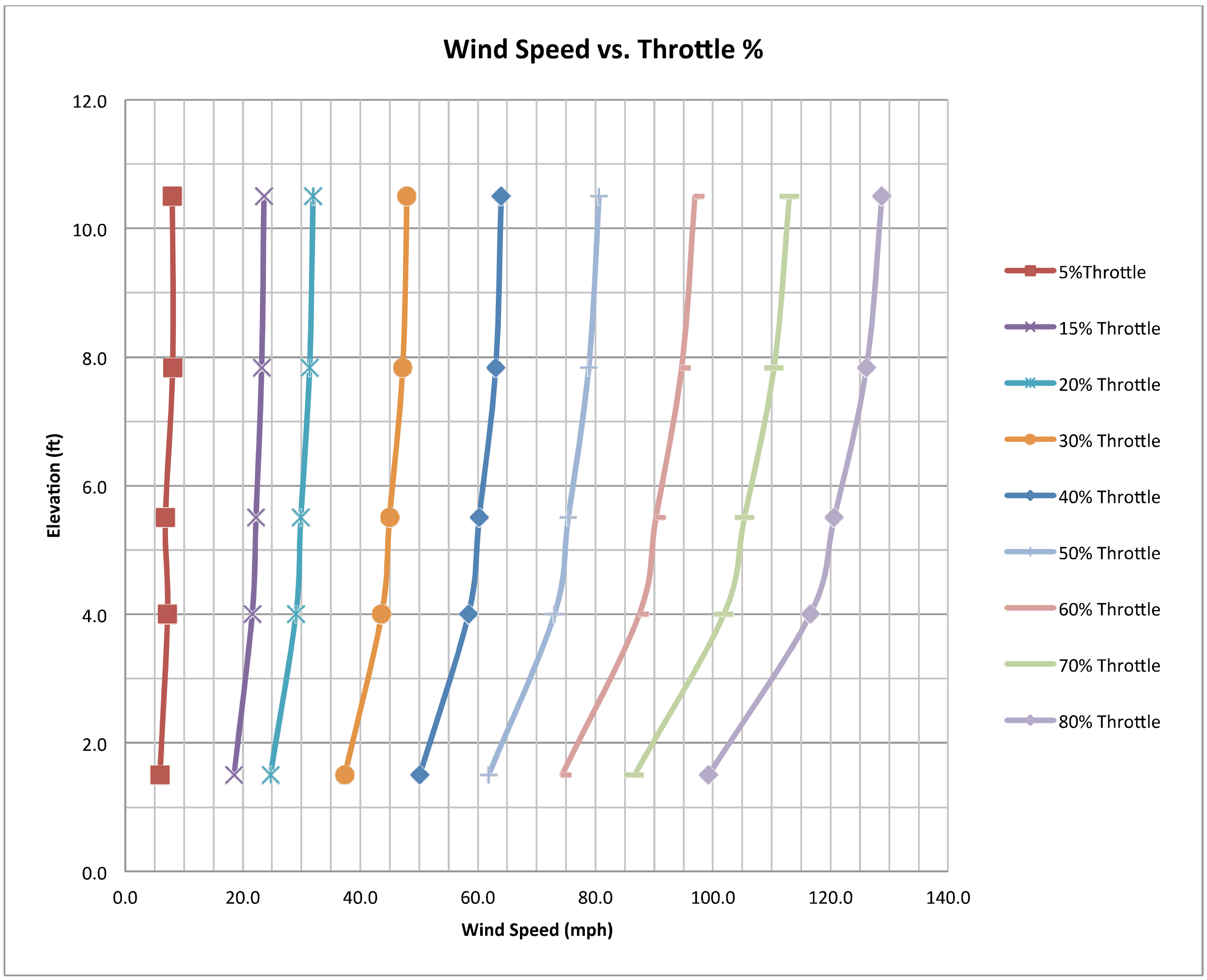


Figure 4: Graph showing wind speed profile vs. throttle percentage

Appendix B – Selection of test pictures

Figure 5: Installation of Storm Stoppers Original 3/8 in. on rear window.

Figure 6: Storm Stoppers Original 3/8 in. window panel with removal handle strap and black dots indicating location of 3M® Dual Lock® Reclosable Fasteners.

Figure 7: Storm Stoppers Original 3/8 in. door panel with removal handle strap and black dots indicating location of 3M® Dual Lock® Reclosable Fasteners.

Figure 8: Side view of Storm Stoppers Original 3/8 in. plastic panel.

Figure 9: Window showing locations of 3M® Dual Lock® Reclosable Fasteners.

Figure 10: Windows showing location of 3M® Dual Lock® Reclosable Fasteners.

Figure 11: Test house showing installed Storm Stoppers Original 3/8 in. door panel and window panel before installation.

Figure 12: Test house showing installed Storm Stoppers Original 3/8 in. door panel and window panels before installation (Left Side)

Figure 14: Test house rolled 50 feet away after foundation failure.

Figure 13: Test house showing installed Storm Stoppers Original 3/8 in. door panel and window panels before installation (Right Side)

Appendix C – Technical Aspects of the Wall of Wind

Source: wow.fiu.edu/about/technical-aspects-of-the-wall-of wind

The WOW is an open-circuit wind tunnel. The open jet characteristic allows WOW to test up to failure without worrying about flying debris recirculating into the fan system.

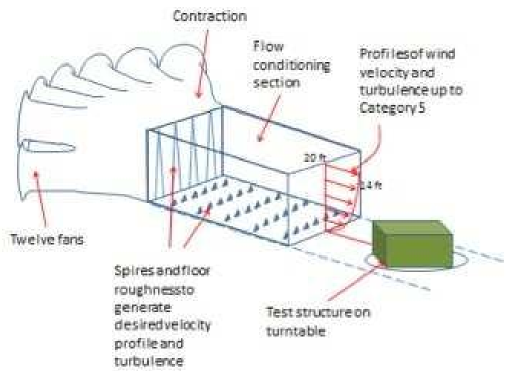


Figure 14 - Schematic of the Wall of Wind components

Wall of Wind uses **12** electric fans, each capable of producing a maximum flow of **240,000 CFM** at **700 HP**, for a combined flow of **2,880,000 CFM at 8000 HP**. The WOW is an open return, subsonic wind tunnel facility. The system is a blower type, with 12 fans located at the intake section in an arc-focal arrangement. The fans push air into a contraction chamber that increases the wind speed and smooths out the speed variations. The flow then travels through a set of triangular spires and floor roughness elements that generate turbulence and boundary layer characteristics (see Figure 14).

The WOW was designed to model the turbulent characteristics of the bottommost layer of the atmosphere known as the atmospheric boundary layer (ABL). Matching these characteristics for wind engineering purposes is important due to the fact that most of manmade structures are located within this layer of the atmosphere. After the wind flows through the contraction, it is conditioned by flow management devices that give it desired velocity profiles and turbulence characteristics.

BOUNDARY LAYER

ABL characteristics vary with the conditions of the terrain considered. Design standards (as ASCE7-10 Minimum Design Loads for Buildings and Other Structures) take it into consideration and factor the effect of surrounding structures and terrain in the load conditions of the structure of interest. Three different types of terrain will affect shape and thickness of the boundary layer: open terrain, suburban and urban areas and flat unobstructed areas (Figure 15).

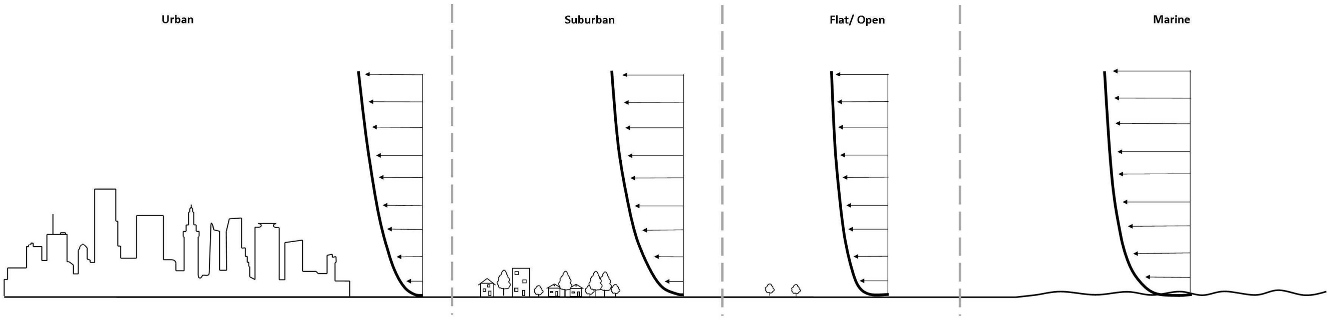


Figure 15 - Graphic representation of boundary layer profiles over different types of terrain

TURBULENCE

Besides the wind speed profile (varying with height) for each surface roughness condition, each will have a particular turbulence content in the flow. In nature, flow rarely occurs in laminar form. Turbulence will be present at different intensities and directions for each case. Thus the importance of properly modeling the characteristics of the flow before the tests happen.