**Scope of Work**

**Experimental Evaluation of Pressure Equalization Factors and Wind Resistance of Vinyl Siding Systems Using a Multi-Chamber Pressure Test Bed**

The State of Florida Department of Business and Professional Regulation

Florida Building Commission

And

University of Florida, Engineering School of Sustainable Infrastructure and Environment

(ESSIE)

Project Leader: David O. Prevatt, PhD Civil Eng., F. ASCE, Univ. of Florida

# Introduction

The University of Florida, Engineering School of Sustainable Infrastructure and Environment (ESSIE) shall conduct experimental studies using the vinyl siding pressure test chamber that has been built in Project Phase I. Identifying the effects of spatio-temporal varying loads on the pressure distributions on vinyl siding wall systems. The project will be led by David O. Prevatt, Associate Professor of Civil Engineering, in collaboration with Dr. David Roueche, Assistant Professor, from Auburn University (sub-contract). See attached resumes.

# Relevant Sections of the current Florida Building Code (FBC) and proposed next update to the FBC (and related documents)

* Florida Building Code- Residential, Sixth Edition Chapter 7- Wall Covering

Chapter 2, section 202, defines vinyl siding as a shaped material, made principally from rigid polyvinyl chloride (PVC) that is used as an exterior wall covering.

**R703.11.1** Installation

**R703.11.1.1** Fasteners

**R703.11.1.2** Penetration depth

**R703.11.1.3** Spacing

**R703.11.1.4** Vinyl soffit panels

**R703.11.2** Installation over foam plastic sheathing

 **R703.11.2.1** Basic wind speed not exceeding 115 miles per hour and Exposure B

**R703.11.2.2** Design wind pressure rating

**R703.11.2.3** Manufacturer specification

**R703.13** Insulated vinyl siding shall be certified with ASTM D7793

**R703.3** Nominal thickness and attachments for exterior wall covering

**R703.11** Vinyl Siding states that vinyl siding shall be certified and labeled as conforming with ASTM D3679

* Florida Building Code- Building, Sixth Edition Chapter 14- Exterior Walls

**Section 1404.9** “Vinyl siding shall be certified and labeled as conforming to the requirements of ASTM D3679 by an approved quality control agency.”

**Section 1405** Installation of wall coverings. **Table 1405.2** - weather protection, minimum thickness of vinyl siding 0.035. **1405.14**- Vinyl siding overview. **1405.14.1** Application- installation requirements

* Relevant sections/chapters of the proposed changes to the 6th Edition (2017) FBC for inclusion in the 7th Edition (2020) update to the FBC.
* Related documents:

**ASTM D5206-13** Standard Test Method for Wind Load Resistance of Rigid Plastic Siding.” ASTM International, West Conshohocken, PA, 2013, [www.astm.org](http://www.astm.org)

**ASTM D3679-11/17** Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Siding.” ASTM International, West Conshohocken, PA, 2017, [www.astm.org](http://www.astm.org)

**ASTM D4477-16**, Standard Specification for Rigid (Unplasticized) Poly (Vinyl Chloride) (PVC) Soffit, ASTM International, West Conshohocken, PA, 2016, [www.astm.org](http://www.astm.org)

# Scope of Work

1. Develop performance characteristics of the multi-chamber pressure test bed, including vinyl siding installation methods, peak pressures characteristics, and pressure frequency response.
2. Review the literature in the public domain on wind resistance testing and pressure-equalization factors for vinyl siding systems. Derive a pressure test protocol that represents typical wind pressure distributions (wind pressure distribution from cornering winds on side and leeward building surfaces), in order to measure pressure equalization factors occurring on a vinyl siding system installed on a single-family residential scale structure IBHS (Cope et al. 2012; Morrison and Cope 2015) and UWO (Miller et al. 2017), (Tamura 2012).
3. Select two vinyl siding systems from our damage database for conducting tests. Review product approval standards and specifications and identify the wind resistance (per ASTM D5206 test protocol) for each system, which will be used as a baseline for current tests. Document the geometry of the two systems and their installation into the test bed.
4. Develop a test matrix for simulating the extremes of vinyl siding wind loading characteristics identified in Task 3(b) above. The test matrix if possible will replicate the dynamic cornering wind pressure distributions that were targeted based on analysis of the Hurricane Irma and Michael damage database.
5. Simulate the spatio-temporal pressure variations on the two vinyl siding systems, with at least two pressure distributions up to the peak suction on the siding due to cornering winds, and one representing the leeward face of the installed vinyl siding. Record the PEFs, chamber pressures and all failure mechanisms observed (if any).
6. Analyze results to produce an enveloped table of pressure equalization factors and pressure distributions.
7. Summarize the experiment in a written report outlining the goals, scope, test procedures, results analysis and conclusions. Make recommendations for a modified or new test procedure for incorporation into future FBC for determining the PEF and wind resistance characteristics of vinyl siding cladding systems.

# Method of Payment

A purchase order will be issued to the University of Florida/ Engineering School of Sustainable Infrastructure and Environment (ESSIE). This project shall start on the date of execution of the purchase order and end at midnight on June 30, 2020, shall not exceed $126,593, and shall cover all costs for labor, materials, and overhead. Payment will be made for the study after the Contract Manager, Program Manager and the Commission’s Structural Technical Advisory Committee (TAC) have approved the final report.

# Deliverables

1. An interim report shall be prepared and delivered to the FBC on March 17, 2020. The Interim report will summarize the results of task a and the current status of task b. These tasks comprise preliminary tests and subtasks from the parametric study. The Interim report will describe the tests that have been executed at the time, the parameters that have been varied, as well as the failure mechanisms found. The report shall be presented to the Commission’s Structural Technical Advisory Committee (TAC) at a time agreed to by the Contractor and the Department’s Program Manager.
2. A final report shall be prepared and delivered no later than June 19, 2020 comprising of the information in the interim report augmented by TAC feedback and including test results, Pressure equalization factors recommended for the two systems, the failure mechanisms observed (if any) and recommendations for a future Product Approval standard for vinyl siding systems.

# Performance Measures and Financial Consequences

ESSIE is solely and uniquely responsible for the satisfactory performance of the tasks and completion of the deliverables as described in this Scope of work.

Failure to complete the task and deliverables in the time and manner specified in Sections 3 and 5 shall result in a non-payment of invoice until corrective action is completed as prescribed by the program manager or contract manager.

# Contract Manager and Program Manager

The Contract Manager for this purchase order is Barbara Bryant and the Program Manager is Mo Madani.

# Goals

The goals of this research are the following:

1. To commission the vinyl siding multi-chamber pressure test bed as a viable option to evaluate the wind resistance performance of a vinyl siding system.
2. To perform an experimental research plan for a parametric study to evaluate multiple wind loading configurations on the vinyl siding that will generate a robust range of Pressure Equalization Factors (PEFs).
3. To use a multi-chamber pressure test bed and replicate field damage failure mechanisms on vinyl siding.
4. To recommend the most appropriate methodology for test Product Approval of vinyl siding systems.

# Objectives

1. Evaluate the range of net pressures and pressure equalization factors that occur for typical vinyl siding installed on wood sheathed walls subjected to realistic wind flow regimes.
2. For two vinyl siding systems, simulate the full-scale spatio-temporal pressure distributions that would have occurred on an observed vinyl siding clad wall system during Hurricane Michael and compare observed to simulated failure mechanisms.
3. Recommend a reasonable Pressure Equalization Factor values appropriate for the tested vinyl siding systems. Comment upon the recommended PEF values versus the code-recommended ones.

# Background

Over the past one hundred years, hurricane events have caused more than one trillion dollars in losses (2017 dollars) in the United States (Baradaranshoraka et al. 2017). Vinyl siding, a common type of cladding material, commonly failed during Hurricane Katrina and was reported as the initial source for more extensive damage like gable end wall losses through progressive failure mechanisms (van de Lindt et al. 2007). More recently, damage assessments performed after Hurricane Irma and Michael have also found failures for residential homes with vinyl siding as the cladding material (FEMA 2018; Roueche et al. 2018).

The University of Florida conducted damage surveys after Hurricane Irma to assess the impact of the Florida Building Code (FBC) on residential building performance. This code was established on March 1, 2002 after wind resistant upgrades were needed due to the losses from past hurricane wind events. During Hurricane Irma 278 houses with vinyl siding cladding were assessed and 53% of those were associated with vinyl siding failures. The assessment was performed using Fulcrum mobile smartphone application developed by Spatial Networks (2017) which provided a standardized damage assessment procedure following methodologies from (Gurley et al. 2017). The report identified and recommended more profound studies on the premature failures of vinyl siding systems since Hurricane Irma was not a design level event (Prevatt et al. 2018).

Phase one of this project studied the performance of vinyl siding by combining datasets from observations of Hurricane Irma and Hurricane Michael. For Hurricane Michael, the performance of 125 homes with vinyl siding, vinyl soffit and fascia were quantified with respect to where the materials were located on the building, and the building orientation relative to the wind angles of attack. Data analysis identified 20% average vinyl siding detachment for 64 Pre-FBC buildings and a 10% average vinyl siding detachment for 64 Post-FBC buildings. The report also identified a moderate trend for increasing vinyl siding damage occurring at cornering wind angles of attack.

In order to understand the observed failures and actual loading conditions, researchers fabricated a multi-chamber test bed to develop reasonable pressure equalization factor tests that replicate the testing performed on full scale buildings in the IBHS wind tunnel. Failure mechanisms and pressures will be studied and compared to those observed from Hurricane Irma and Hurricane Michael datasets. The testing of vinyl siding walls will be the second phase of this project and will be the catalyst in developing recommendations for current test approval methods.

# Motivation and Purpose

The motivation of this research is to develop more realistic pressure distributions across vinyl siding specimens and determine appropriate Pressure Equalization Factors. Experimental tests using a spatio-temporal wind pressure loading actuator will produce these PEFs, which will inform as to whether failures observed in the field following Hurricanes Irma and Michael were premature. The research will advance current knowledge on spatiotemporal wind loading effects and will calibrate current test standards to more realistic approaches.

# Current Vinyl Siding Test Standards

ASTM D3679 (2017) is the standard specification for rigid PVC/ vinyl siding. This document refers to ASTM D5206 (2013) for wind loading protocols to determine vinyl siding resistance. ASTM D5206 utilizes a step and hold loading methodology with increments of 5 psf uniform pressure increments. The Wind Load Resistance Test Design Factors in Annex 1 of ASTM D3679 utilize pressure equalization factors (PEFs) which reduce the design load. PEFs were developed due to discontinuities in vinyl siding which allow for airflow-through effects, enabling interaction between the cavity and the exterior of the cladding system. A reduction of 64% of the external wind pressure was recommended by previous versions of ASTM D3679, and recently the standard changed to a 50% external pressure reduction. Current test methods assume that uniform pressure tests replicate the same failure mechanisms, although wind realistic spatial and temporal variations are not replicated.

In recent years, several studies have been conducted to develop more realistic non-uniform pressure loading on vinyl siding systems. The Insurance Institute for Business and Home Safety (IBHS) reported that external pressures on vinyl siding should only be reduced by approximately 30% (Cope et al. 2012; Morrison and Cope 2015). Florida International University conducted testing which found that current design standards for vinyl siding can lead to local failures in smaller tributary areas such as the design of connections (Moravej et al. 2016). Multichamber testing at the University of West Ontario resulted in similar PEFs for vinyl siding walls than those observed by IBHS (Miller et al. 2017). Based on the current research observations, vinyl siding specimens which failed during Hurricane Irma and Hurricane Michael could have been exposed to actual design loads if a smaller load reduction should be implemented based on the past studies.

# Anticipated Budget and Justification

The UF is a land-grant institution that is today a large public university offering a full spectrum of educational opportunities. The Engineering School for Sustainable Infrastructure and Environment is working with Florida Technical College.

# Budget Estimate (To be Completed after receiving budge directive from FBC Staff)

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| Test agency budget | UF Budget Breakdown |
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# UF Budget Breakdown by Labor Hours

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Person** | **Hours** | **Hourly Rate** | **Fringe** | **Tuition** | **IDC** | **Total** |
| D. Prevatt |  |  |  |  |  |  |
| Admin Assistant |  |  |  |  |  |  |
| Grad Student |  |  |  |  |  |  |
| Undergraduate Students |  |  |  |  |  |  |

# References

Baradaranshoraka, M., Pinelli, J.-P., Gurley, K., Peng, X., and Zhao, M. (2017). "Hurricane wind versus storm surge damage in the context of a risk prediction model." *Journal of Structural Engineering*, 143(9), 04017103.

Cope, A., Crandell, J., Johnston, D., Kochkin, V., Liu, Z., Stevig, L., and Reinhold, T. (2012). "Wind Loads on Components of Multi-Layer Wall Systems with Air-Permeable Exterior Cladding." *Advances in Hurricane Engineering*, American Society of Civil Engineers, 238-257.

FEMA (2018). "Florida Mitigation Assessment Team - Hurricane Irma."Washington D.C.

Gurley, K. R., Roueche, D. B., Wong-Parodi, G., Castillo-Perez, R., Mimms, M., Ozimek, Q., Egnew, A., and Yaghoubi, H. (2017). "Survey and Investigation of Buildings Damaged by Category III Hurricanes in FY 2016-17–Hurricane Matthew 2016." Florida Department of Business and Professional Regulation, Tallahassee, FL, USA.

Miller, C. S., Kopp, G. A., Morrison, M. J., Kemp, G., and Drought, N. (2017). "A Multichamber, Pressure-Based Test Method to Determine Wind Loads on Air-Permeable, Multilayer Cladding Systems." *Frontiers in Built Environment*, 3, 7.

Moravej , M., Zisis , I., Chowdhury , A. G., Irwin, P., and Hajra , B. (2016). "Experimental Assessment of Wind Loads on Vinyl Wall Siding." *Frontiers in Built Environment*, 2, 35.

Morrison, M. J., and Cope, A. D. (2015). "Wind performance and evaluation methods of multi-layered wall assemblies." *Structures Congress 2015. Proceedings*, 2735-2748.

Prevatt, D. O., Gurley, K. R., Roueche, D. B., and Wong- Parodi, G. (2018). "Final Report: Survey and Investigation of Buildings Damaged by Category  II, III, IV and V Hurricanes in FY 2017- 2018- Hurricane Irma 2017." University of Florida, Gainesville, FL.

Roueche, D., Cleary, J., Gurley, K., Marshall, J., Pinelli, J.-P., Prevatt, D., Smith, D., A lipour, A., Angeles, K., Davis, B., Gonzalez, C., Lenjani, A., Mulchandani, H., Musetich, M., Salman, A., Kijewski-Correa, T., Robertson, I., and Mosalam, K. (2018). "StEER - Hurricane Michael: Field Assessment Team 1 (FAT-1) Early Access Reconnaissance Report (EARR)." DesignSafe-CI, ed.

Spatial Networks (2017). "Fulcrum App for Android and IOS (Release Version 2.26)."

Tamura, Y. (2012). "Aerodynamic database for low-rise buildings." Tokyo Polytechnic Institute, Global Center of Excellence Program.

van de Lindt, J. W., Graettinger, A., Gupta, R., Skaggs, T., Pryor, S., and Fridley, K. J. (2007). "Performance of Wood-Frame Structures during Hurricane Katrina." *Journal of Performance of Constructed Facilities*, 21(2), 108-116.