FIU Wall of Wind
NHERI Experimental Facility

Scope of Work

Wind-induced loads on ground-mounted and ground ballasted systems

Florida Department of Business and Professional Regulation

Florida Building Commission

And

Laboratory for Wind Engineering Research (LWER), Extreme Events Institute (EEI)

Florida International University (FIU)

Project Lead: Ioannis Zisis

1. Introduction

Residential structures need to cater to different climates and occupancy requirements and needs. As a result, a modern home is equipped with valuable and critical mechanical equipment that is mostly related to heating and/or cooling but often extends to solar energy and water harvesting, alternative fuel sources (e.g. gas, propane, power generator) and secondary structure equipment (e.g. pool mechanical equipment). This equipment is placed in the proximity of the house and is exposed to the same – extreme – loads as the main structure itself. Wind related damage has been documented in the past making the repair or replacement of such equipment an additional financial burden for the homeowners. Most importantly, some of this equipment might have a critical role during and after an extreme wind event; for instance, maintaining the power supply through a gas generator to cool the home and provide basic functions.

The latest Florida Building Code (2020) includes an exception clause for the design of such equipment in both sections 1609 and 1620 (HVHZ) and redirect the user to the 2007 version of the FBC:

> *Exception: Exposed mechanical equipment or appliances fastened to a roof or installed on the ground in compliance with the code using rated stands, platforms, curbs, slabs, walls, or other means are deemed to comply with the wind resistance requirements of the 2007 Florida Building Code, as amended. Further support or enclosure of such mechanical equipment or appliances is not required by a state or local official having authority to enforce the Florida Building Code.*

The 2007 FBC (Building – 1609.1) subsequently redirects the designer to the American Society of Civil Engineers (ASCE) 7-05, Chapter 6. In that – older – version of ASCE 7, section 6.5.15 deals with the design wind loads on other structures and recommends the use of equation 6-28 in conjunction with Fig. 6-21. Nevertheless, the recommended force coefficients have not been based on scientific research specific to ground-mounted equipment and rather refer to some limited studies that were carried out for rooftop mounted equipment.

Remarkably, the recently released 2022 version of the ASCE 7, has kept almost unaltered the design guidelines for ground-mounted equipment in *Section 29.4 Design Wind Loads: Other Structures*. Equation 29.4-1 now includes the wind directionality factor (K_d) and refers to Fig. 29.4-1 for the selection of the appropriate force coefficient. This figure still provides the same recommended Cf values as in the previous ASCE versions, including the ASCE 7-05. An important addition though, is that there is more background information that has been included in the Commentary chapters and in particular Section C29.4:

> *Figures 29.4-1, 29.4-2, and 29.4-3. With the exception of Figure 29.4-3, the pressure and force coefficient values in these tables are unchanged from ANSI A58.1-1972 (ANSI 1972). The coefficients specified in these tables are based on wind tunnel tests conducted under conditions of uniform flow and low turbulence, and their validity in turbulent boundary-layer flows has yet to be completely established. Additional pressure coefficients for conditions not specified herein may be found in two references (SIA 1956, ASCE 1961).*

It is apparent from this clarification that the corresponding design recommendations are completely outdated. In fact, the uniform flow conditions make these recommendations obsolete and require immediate attention and research effort using the necessary scientifically simulated flow conditions that current wind tunnel laboratories can generate.

In addition, to the ground-mounted equipment, this study will be extended to include ground-ballasted systems. This method is mostly used on photovoltaic (PV) systems, but research findings may be translated into residential applications as well. Similar to the ground-mounted equipment, the current versions of both FBC and ASCE 7 do not have specific design guidelines for ground ballasted systems. New provisions for determining wind loads on rooftop solar panels have been added to ASCE 7-16 (Sections 29.4.3 and 29.4.4) but there is no specific reference to systems that are at ground level. Several previous reconnaissance reports clearly identified the significant damage that was induced on such systems following extreme wind events.

Taking into consideration the above information, we propose to conduct full-scale testing of representative ground-mounted and ground-ballasted systems to generate code-ready design force coefficients that will enhance the Florida Building Code as well as the ASCE 7 Wind Standard. The team will be comprised by wind engineering experts from Florida International University (FIU), Laboratory for Wind Engineering Research (LWER), Extreme Events Institute (EEI) (henceforth FIU LWER/EEI) and from Concordia University's Building Aerodynamics Laboratory.

2. Scope of Work

Task 1 – Physical Testing Campaign

The objective of this task is to identify common installation practices for both ground-mounted and ground-ballasted systems and design and execute full-scale physical testing at the Wall of Wind (WOW) Experimental Facility (EF) at FIU.

The anticipated actions within this task are the following:

- FIU LWER/EEI shall consult with industry representatives in South Florida to identify current installation practices and products and that they will inform and develop the test campaign at the WOW-EF. A detailed description of the testing protocols and product parameters adopted in the WOW-EF tests shall be developed. FIU LWER/EEI shall define all important flow field simulation parameters, including the upstream terrain characteristics, the wind speed and turbulence intensity profiles, the power spectrum and the WOW developed Partial Turbulence Simulation approach that is used in large-scale model studies. Last but not least, the necessary number of wind directions to be tested shall be defined for each model configuration.
- FIU LWER/EEI shall perform WOW tests to acquire wind-induced pressure or force data. When possible, pressure or load sensors will be incorporated into the tested specimens. If that is not possible (e.g. ballasted systems) the wind speed, at which initiation of damage is observed, will be recorded.

Task 2 – Data Interpretation and Codification

The objective of this task is to analyze the data collected during the experimental campaign at WOW and proceed with their interpretation is such format that can be utilized by the Florida Building Code as well as the ASCE 7 wind load committees.

- FIU LWER/EEI shall analyze the pressure, force or wind speed data and present findings in a user-friendly format. This shall include mean and peak pressure/force coefficient variation as a function of the wind direction.
- FIU LWER/EEI shall utilize the data from the experimental task towards the development of code-ready output by applying codification approaches worked successfully in the past. These consist of comparison, generalization and simplification of large quantities of data in order to produce simplified diagrams suitable for incorporation in building codes and wind standards.
- FIU LWER/EEI shall compare the findings of the current research project to the ASCE 7-16 Wind Standard (also adopted by the Florida Building Code). Agreement and/or deviations from current design recommendations shall be identified and cases that are currently not considered shall be considered for future recommendation and code enhancement.

Task 3 – Evaluation of the FBC related requirements and recommendations for future inclusion

- FIU LWER/EEI shall evaluate the Florida Building Code, 7th Edition, (2020), (FBC) requirements to recommend what additional steps will be necessary to incorporate results of the proposed study into the appropriate sections of the FBC. FIU LWER/EEI shall provide specific recommendations for modifications to the Florida Building Code that are necessary to incorporate results of the proposed study into the FBC.

3. Staffing

Personnel

PI: Ioannis Zisis, Associate Professor, CEE, Florida International University, USA

Co-PI: Ted Stathopoulos, Professor, BCEE, Concordia University, Canada

Graduate Student: TBD, Florida International University, USA

4. Method of Payment

A purchase order will be issued to the Florida International University. This project shall start on date of execution of the purchase order and end at the midnight on June 30, 2023. This purchase order shall not exceed $118,000 and shall cover all costs for labor, materials and overhead. Payment will be made for the study after the Program Manager and the Florida Building Commission's Hurricane Research Advisory Committee have approved the final report. Additionally, the Contractor agrees to provide additional documentation requested by the Program Manager to satisfy all payment and audit requirements.

5. Deliverables

a. An interim report shall be prepared and delivered no later than February 28, 2023. The interim report shall contain the deliverables of Task 1 and any preliminary findings from Task 2; i.e. a detailed description of the testing protocols and model parameters adopted in the WOW-EF tests. In addition, the interim report shall be formally presented to the Florida Building Commission's Hurricane Research Advisory Committee at a time agreed to by the Contractor and Department's Program Manager. The due date may be extended with the approval of the Department of Business and Professional Regulation's ("Department") Program Manager.

b. A final report shall be prepared and delivered no later than June 1, 2023. The final report shall contain deliverables of the first three Tasks as discussed in Section 2. This shall include force coefficients in different formats (e.g. function of wind direction, contour plots and/or area averaged), simplified diagrams suitable for incorporation in building codes and wind standards and recommendations that are necessary to incorporate results of the proposed study into the appropriate sections of the FBC and ASCE. In addition, the final report shall be formally presented to the Commission's Hurricane Research Advisory Committee at a time agreed to

by the Contractor and Department's Program Manager. The due date may be extended with the approval of the Department of Business and Professional Regulation's ("Department") Program Manager.

6. Financial Consequences

FIU LWER/EEI is solely responsible for the satisfactory performance of the tasks and completion of the deliverables as described in this Scope of Work. Failure to complete the tasks and deliverables in the time and manner specified in Sections 2 and 5, shall result in a non-payment of invoice until corrective action is completed as prescribed by the program or contract manager.

7. Program Manager

The Program Manager for this project is Mo Madani. Mo Madani's email address is Mo.Madani@myfloridalicense.com and his phone number is 850-717-1825.