Interim Report:

Survey and Investigation of Buildings Damaged by Category III, IV and V Hurricanes in FY 2022-2023 - Hurricane Ian

Project #: P0266604

Submitted to:

Florida Department of Business and Professional Regulation

Mo Madani, Program Manager
Building Codes and Standards
1940 North Monroe Street
Tallahassee, Florida 32399

Prepared by:

David O. Prevatt, Ph.D., PE (MA)
Principal Investigator
Associate Professor (Structures)

David B. Roueche, Ph.D.
Co-Principal Investigator
Auburn University, Alabama

Kurtis R. Gurley, Ph.D.
Co-Principal Investigator
Professor, University of Florida

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Engineering School of Sustainable Infrastructure and Environment
Department of Civil and Coastal Engineering
University of Florida
365 Weil Hall
P.O. Box 116580
Gainesville, FL 32611-6580

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1 INTRODUCTION

Researchers at the University of Florida coordinated and led efforts in the field to capture the performance of building structures impacted by Hurricane Ian that made landfall on Florida's Gulf Coast creating extreme storm surge impacts and high winds to several communities there. We conducted joint field efforts with researchers from the National Science Foundation (NSF)-supported Structural Extreme Reconnaissance Network (StEER), carrying out case study observations of damaged buildings, and to capture Streetview photography and overhead photographs using unmanned aerial vehicles (UAVs) of the impacted communities.

Our work to date has included an initial triage assessment of the residential property damage, two in-person presentations of this information to the Florida Building Commission (October 2022, and December 2022), and analysis of observations as related to the Florida Building Code.

1.1 Objectives

The objective of this Interim Report is to provide an update on the status of completion of the five tasks in our Scope of Work. Specifically, the report explains the methodology used in the sub-tasks of Task 5, and our data collection efforts, supplemental data sources, and providing plans for the Data Enrichment efforts.

1.2 Relevance to the Florida Building Code

This project will stratify building performance by building code era, hazard intensity, first floor elevation, and other notable features to facilitate an evaluation of building performance under the latest buildings codes contrasted with those from earlier code editions. Specific code-related topics that will be evaluated include performance of breakaway walls relative to code provisions, placement of the coastal construction control line, evidence for surge-induced floor slab uplift forces, and performance of common roof cover and wall cladding elements.

2 SUMMARY OF HURRICANE IAN (2022) IMPACTS

On September 28, 2022, Hurricane Ian made landfall near Cayo Costa, FL as a Category 4 hurricane according to the National Hurricane Center, with peak sustained wind speeds over water estimated at 150 mph (NHC 2022a), a minimum surface pressure of 940 mb, and preliminary storm surge inundation measurements of 13 ft relative to NAVD88 (USGS, 2022). The impacts of this hurricane were catastrophic in terms of both damage to infrastructure and loss of human life on the densely populated west coast of Florida, particularly in the barrier islands off Ft. Myers and Cape Coral.

Tragically, preliminary numbers available at the time of this report confirm that Ian has caused over 100 fatalities in Florida, the highest direct loss of life in any hurricane landfalling in Florida since the 1935 Labor Day hurricane. The fatalities are primarily associated with the heavy storm-surge that struck the barrier islands of Sanibel, Ft. Myers Beach, and Bonita Beach. Wind damage was generally less severe, because peak wind speeds of Hurricane Ian were at or below the Florida Building code design wind speed, (ex. Cape Coral: 156 mph 3-second gust wind speed,) for the impacted areas. However, widespread roof cover loss still occurred, resulting in subsequent water ingress and building contents damage as well as other building envelope damage that will drive economic losses. Extensive inland flooding due to heavy rainfall was reported across Florida and into the Carolinas as Ian made a second landfall there.

Hurricane Ian will likely be one of the costliest landfalling hurricanes of all time in the US, despite it being a below-design wind event. Risk modelers estimated wind and coastal storm surge losses of $40-$74 billion. These estimates do not include losses due to inland flooding covered by the National Flood Insurance Program (NFIP) and uninsured losses, which are likely to be high given the extensive inland flooding and low percentage of homes with flood insurance in these areas.

Hurricane Ian made landfall in almost the same location Hurricane Charley did 18 years earlier, with similar peak sustained wind speeds. However, the damage from Hurricane Charley was primarily driven by high winds concentrated within a narrow band produced by that relatively small diameter hurricane. In contrast, Hurricane Ian was a larger storm (National Hurricane Center reported the tropical storm-force wind field peak diameter of Ian was 2.3 times the diameter of Charley just before landfall) and as a result Hurricane Ian drove a much higher storm surge producing water upwards of 13 ft above NAVD88 based on preliminary measurements.

The surge impacted regions with high population densities housed in both elevated and on-grade residential structures, including mobile and manufactured home parks, along hundreds of miles of canals and coastal frontage in Cape Coral, Ft. Myers, and nearby barrier islands. Despite the lessons on wind mitigation learned from Hurricane Charley 18 years earlier, these communities were ill-prepared for the storm surge and flooding produced by Hurricane Ian, highlighting vulnerabilities that likely exist in many similar communities along coastlines around the US.

Note: The above summary of Hurricane Ian's impacts is taken from a comprehensive assessment of Hurricane Ian (2022) led by the Structural Extreme Events Reconnaissance (StEER) network (Kijewski-Correa et al. 2021) which was published in the form of two documents; Hurricane Ian Preliminary Virtual Reconnaissance Report (PVRR) (Cortes et al. 2022) and the Hurricane Ian Early Access Reconnaissance Report (EARR) (Prevatt et al. 2023). The report covered the meteorological history of Hurricane Ian, observed impacts to the built infrastructure, and the regulatory context surrounding the performances. PIs Prevatt and Roueche contributed to the synthesis of knowledge and writing of the StEER reports.

3 STATUS UPDATE ON TASKS

There are five tasks in our scope of work, and this section outlines the status of each deliverable.

Task 1. Deploy equipment for measuring intensity of land-falling hurricanes.

- Florida Coastal Monitoring Program led by UF Professors Brian Phillips and Forrest Masters successfully deployed two towers between 26-29 September 2022. Appendix A provides details of the deployment and observations.

Task 2. Conduct one deployment training exercise if necessary.

- Nothing to report.

Task 3. Perform field data collection preparation.

- Nothing to report.

Task 4. Organize and execute an initial triage assessment of residential property damage resulting from a Category III, IV, or V hurricane.

- PI Prevatt performed triage assessments on September 29, 2022, and again on October 2-3, 2022. Assessments were presented to the Florida Building Commission at the 11 October 2022 and 13 December 2022 meetings. We leveraged additional personnel resources for this exercise coordinating through the StEER Network, including teams led by Florida International University Professor Ioannis Zisis and teams led by UF Professor David O. Prevatt.

Task 5. Organize and execute a formal survey and damage assessment effort.

- Observations from the triage deployments are included in the StEER Early Access Reconnaissance (EARR) report (Kijewski-Correa et al. 2023), a portion of which related to observed performance is provided in Appendix B.
- StreetView Panoramic Imagery: PIs Prevatt and Roueche coordinated the collection of over 650+ miles of surface-level panoramic imagery throughout the impacted region, and over eight square miles of aerial imagery captured by a low-altitude Unmanned Aerial Systems (UAS) in collaboration with StEER and the NSF NHERI RAPID Experimental Facility (Berman et al. 2020)[1]. Each of these data sources are available to the research team for its use in the current project.
- PI Gurley participated in a robust deployment between October 19-23, 2022, coordinated by StEER. The performance assessment team, including PI Gurley, consisted of seven practicing civil engineers and engineers in academia. The team assessed the performance of both residential and commercial structures primarily on Sanibel and Fort Myers Beach, conducting 274 assessments in total.
- Highwater marks: A research team led by StEER member and Professor James Kaihatu of Texas A&M University surveyed and documented the highwater marks in the area between October 31 and November 4, 2022. The analyzed data is being processed and will be published in a separate peer-reviewed data paper.

Task 5.1. Enrichment of Reconnaissance Data.

- A sample set of candidates for virtual assessments was generated, including the following subsets:
  - All residential StEER performance assessments (N=274). These on-site performance assessments were captured using the Fulcrum field data collection app-based platform (Spatial Networks 2018). The dataset includes photographs, and audio recordings of field observations, and limited building attributes and damage information on each structure. The locations of the on-site assessments were chosen to obtain representative samples of residential and critical facility performance in Sanibel and Ft. Myers Beach across the expected coastal hazards gradient (wave action and surge inundation).
  - We collected a stratified, random sample set (N = 691) of structures from within the domain of Lee County and Charlotte County buildings that were along the route

[1] The Natural Hazards Engineering Research Infrastructure (NHERI) RAPID Facility is funded by the National Science Foundation to provide investigators with equipment, software, and support services needed to collect, process, and analyze perishable data from natural hazard events. More information is available at https://rapid.designsafe-ci.org/.

and visible in the 650+ miles of post-Ian street-level panoramic imagery captured by StEER and SiteTour 360. Residential buildings within this domain were stratified across the following features:

- Occupancy type (Single Family, Multi-Family (including Condominiums))
- Code era of construction (pre-2002, 2003-2005, 2006-2010, 2011-2017, 2018-2022)
- Hurricane Ian wind zone (80-99, 100-109, 110-119, 120-129, 130-140 mph maximum 3 second gust).
- Proximity to high water mark (within 50 ft, outside of 50 ft)

We endeavored to draw representative samples of buildings such that there were approximately 15 single-family residential and 5 multi-family residential buildings in each sample class. Figure 1 and Figure 2 illustrate the distribution of samples within the various stratification levels.

- We identified a comprehensive suite of features and defined them for inclusion in the enrichment process that would be performed for the sample set of building candidates. The full list is included in Appendix C. In brief, we included features like the estimated 3-second gust wind speed, surge inundation level, base flood elevation, location relative to the Coastal Construction Control Line, number of stories, first floor elevation, roof shape, roof slope, wall cladding material, roof cover material, component-level damage ratios, performance of garage doors (if present), performance of breakaway walls (if present), and retrofit status.
- Our execution of the virtual performance assessments is ongoing. We are using a combination of GIS analysis and automated techniques to evaluate many of the building attributes for each building to increase efficiency of this process, while we are using manual interpretation of the data being used for the damage estimation and characterizing more nuanced features. For example, first floor elevation typically requires manual inspection based on pre-event Google Maps Streetview imagery to identify whether a structure is a 2-story grade-level home or a 1-story elevated home with breakaway walls.

Task 5.2. Performance of Elevated Structures.

- Task 5.2 is being performed in tandem with Task 5.1, with attributes such as first floor elevation, base flood elevation at the home location, performance of breakaway walls, evidence of debris damming, and other fields being part of the enrichment process.
- Fragility of structures conditioned on surge inundation and base flood elevation will be conducted once data enrichment is complete.
- Additional insights are being pulled from review of the detailed on-site photographs captured by the field teams throughout Sanibel and Fort Myers Beach.

At this time, additional on-site deployments to capture new data do not appear necessary but may still be conducted to provide on-site validation of the remote assessment workflow.

4 SUMMARY OF AVAILABLE DATA FOR VIRTUAL ASSESSMENTS

A rich dataset from a variety of sources is available to contextualize the impacts of Hurricane Ian to residential buildings in fulfillment of Tasks 5.1 and 5.2 as described above. These sources are summarized in Table 1 and illustrated in Figure 3.

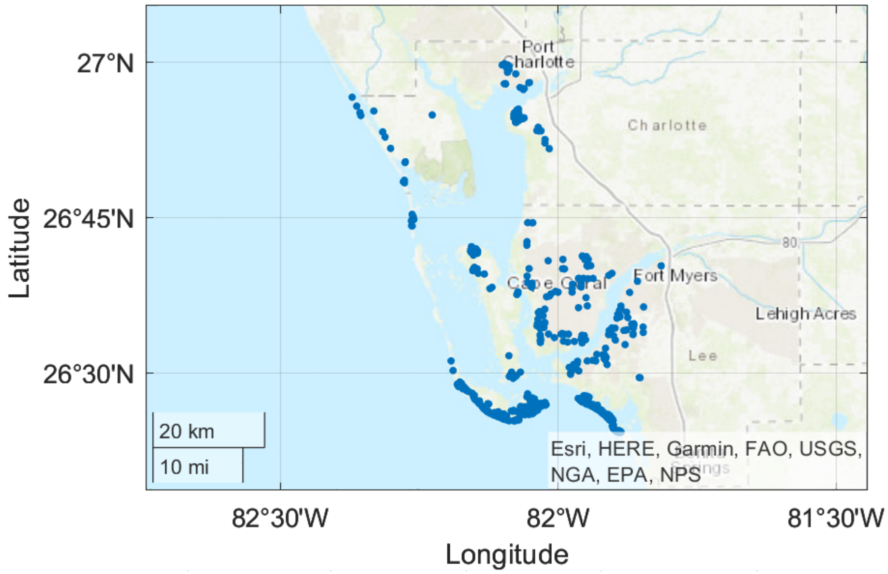


Figure 1. Locations of virtual assessment candidates showing the locations of 650+ buildings in the dataset.

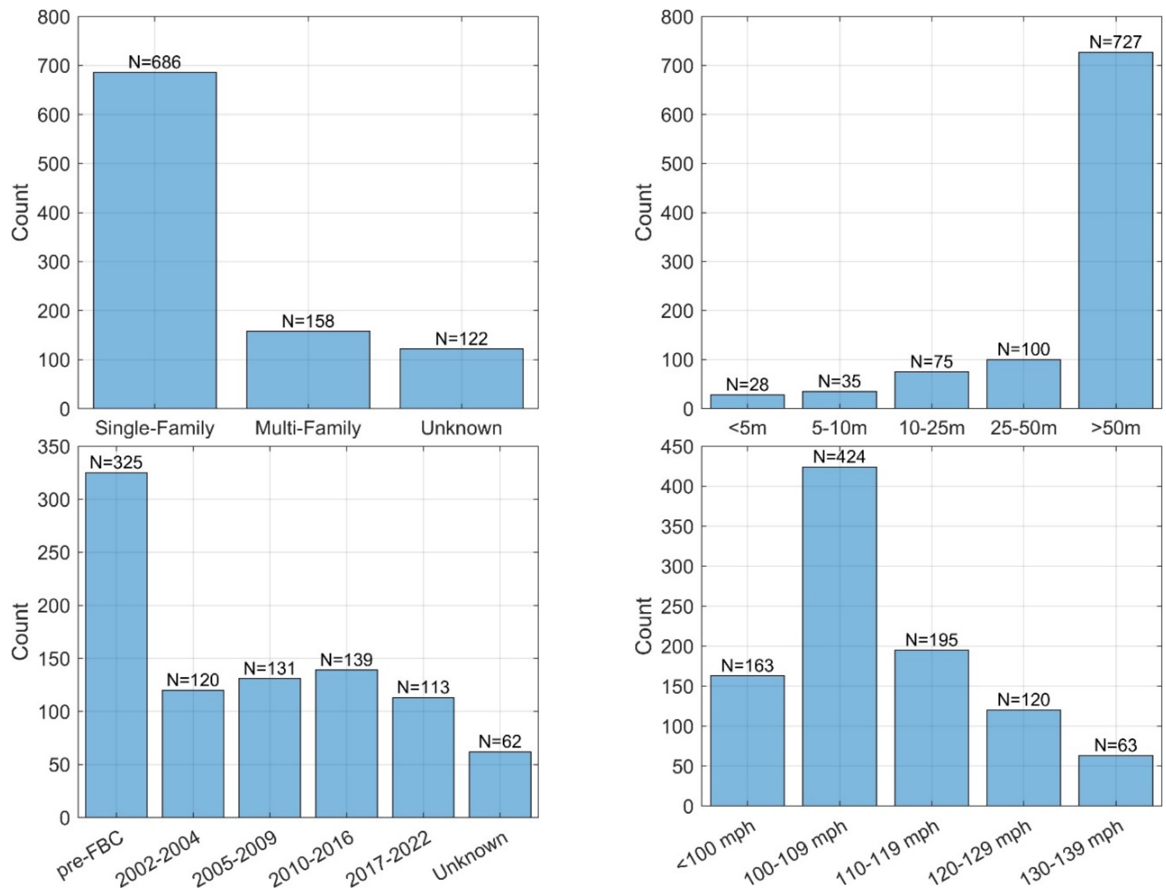


Figure 2. Distribution of samples across various stratification levels, including (a) occupancy class, (b) distance to nearest high-water mark, (c) building code construction era, and (d) estimated 3-second gust wind speed (33 ft height, open terrain).

Figure 1. Primary imagery sources available for conducting virtual assessments, including (a) NOAA nadir aerial images, collected 9-September through 3-October 2022, (b) RAPID nadir aerial imagery, collected 19-23 October 2022, (c) Pictometry oblique imagery, collected 29-30 September 2022, and (d) the Ian street-level panorama viewer created by SiteTour 360 and StEER, including post-Ian NOAA aerial imagery, post-Ian surface-level panoramas collected by SiteTour 360 and StEER, and pre-Ian Google Streetview imagery.

Table 1. Primary data sources in use for performing data enrichment and analysis tasks.

Name	Provider	Data Class	Description	Use to Project
StEER Infrastructure Assessments	Structural Extreme Events Reconnaissance Network	Performance Assessments	On-site post-Ian photographs and basic attributes for select buildings	Starting point for data enhancement
StEER High Water Marks	Structural Extreme Events Reconnaissance Network	Hazard Intensity	High water marks documenting surge inundation throughout the landfall region	Associate observed storm surge with building performance
StEER Surface-Level Panoramas	Structural Extreme Events Reconnaissance Network / SiteTour 360	Imagery	650+ miles of street-level panoramic imagery captured post-Ian	Classify building performance and building attributes
StEER UAS Imagery	Structural Extreme Events Reconnaissance Network / NHERI RAPID EF	Imagery	High-resolution, low-altitude nadir and oblique post-Ian aerial imagery and associated products (3D models, orthomosaics)	Classify building performance and building attributes
USGS High Water Marks	United States Geological Society	Hazard Intensity	High water marks throughout the affected regions	Associate observed storm surge with building performance
Wind Maps	ARA, NIST, FEMA	Hazard Intensity	Interpolated 3-s gust and 1-min sustained wind speeds, standardized to 10 m height and open terrain, throughout the affected regions	Associate estimated wind speeds with building performance
Hurricane Ian Aerial Imagery	National Oceanic and Atmospheric Administration	Imagery	Post-Ian nadir imagery	Classify building performance and building attributes
LCPA Pictometry	Lee County Property Appraiser	Imagery	Pre- and post-Ian, high-resolution, nadir and oblique imagery for Lee County	Classify building performance and building attributes
Lee County Parcel Data	Lee County Property Appraiser	Public Records	Public parcel data for Lee County	Define common building attributes
Lee County Building Footprints	Lee County GIS Department	Public Records	Building footprint polygons and select associated building attributes	Automated evaluation of select building attributes
Lee County Permits	Lee County Permit Office	Public Records	Public permit information for homes in Lee County	Identify retrofits and repairs
Charlotte County Parcel Data	Charlotte County Property Appraiser	Public Records	Public parcel data for Charlotte County	Define common building attributes
Charlotte County Building Footprints	Microsoft	Public Records	Building footprint polygons for Charlotte County	Automated evaluation of select building attributes
Charlotte County Permits	Charlotte County Permit Office	Public Records	Public permit information for homes in Charlotte County	Identify retrofits and repairs
National Lidar Project	United States Geological Survey / Multiple	Digital Twin	Lidar point clouds and derived products covering Lee and Charlotte Counties	Automated evaluation of select building attributes

5 REFERENCES

Berman, J. W., J. Wartman, M. Olsen, J. L. Irish, S. B. Miles, T. Tanner, K. Gurley, L. Lowes, A. Bostrom, J. Dafni, M. Grilliot, A. Lyda, and J. Peltier. 2020. “Natural Hazards Reconnaissance With the NHERI RAPID Facility.” *Front. Built Environ.*, 6.

Cortes, M., P. Arora, L. Ceferino, H. Ibrahim, D. Istrati, D. Reed, D. Roueche, A. Safiey, T. Tomiczek, I. Zisis, M. Alam, T. Kijewski-Correa, D. Prevatt, and I. Robertson. 2022. “StEER: Hurricane Ian Preliminary Virtual Reconnaissance Report (PVRR).” Designsafe-CI.

Kijewski-Correa, T., D. Prevatt, D. Roueche, I. Robertson, M. Alam, A. Safiey, I. Zisis, O. Lafontaine, O. Nofal, L. Rhode-Barbarigos, A. Subgranon, D. Faraone, J. Micali, J. X. Santiago-Hernández, and D. Agdas. 2023. “StEER: Hurricane Ian Early Access Reconnaissance Report (EARR).” Designsafe-CI.

Kijewski-Correa, T., D. B. Roueche, K. M. Mosalam, D. O. Prevatt, and I. Robertson. 2021. “StEER: A Community-Centered Approach to Assessing the Performance of the Built Environment after Natural Hazard Events.” *Front. Built Environ.*, 79. Frontiers.

Spatial Networks. 2018. “Fulcrum App for Android and iOS (Release Version 2.26),.” Spatial Networks.

APPENDIX A. SUMMARY OF FCMP TOWER DEPLOYMENTS IN ADVANCE OF HURRICANE IAN (2022)

Deployment Dates
Monday, September 26, 2022 to Thursday, September 29, 2022

Travelers

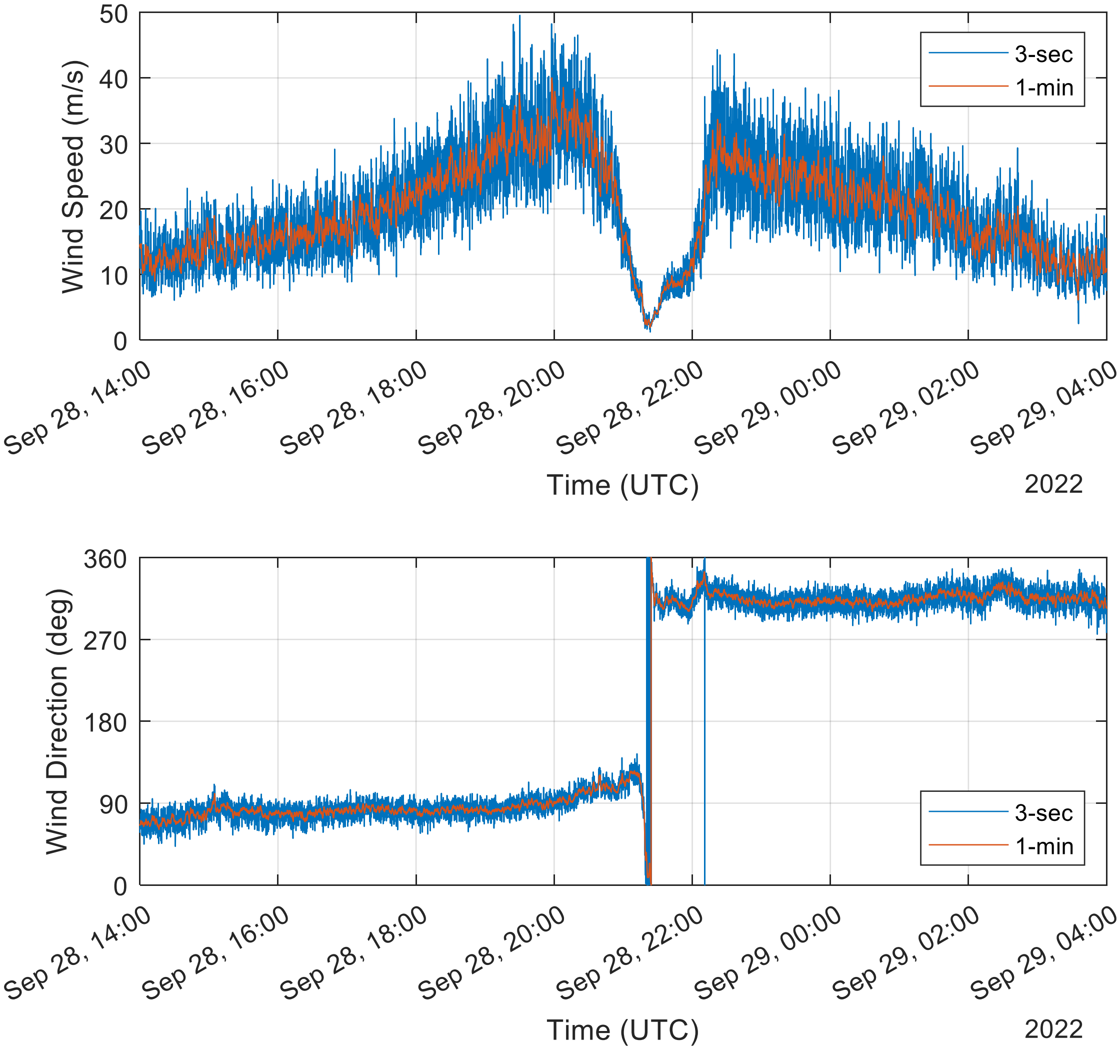
- Alex Esposito
- Chris Ferraro
- Wyatt Kelch
- Forrest Masters
- Ryan Mieras
- Mesa Nicholas
- Ben O'Hern
- Brian Phillips
- Scott Powell
- Taylor Rawlinson
- Ian Van Voris

Tower T1

Latitude: 26.92786
Longitude: -81.99188
https://goo.gl/maps/JQvsZPZosXvSz73z6
Location: Punta Gorda Airport

10-m RM Young Wind Monitor, sampled at 10 Hz

- Max instantaneous wind speed: 53.2 m/s
- Max 3-sec moving average wind speed: 49.6 m/s
- Max 1-m moving average wind speed: 40.0 m/s



Wind Speed (m/s)
50
40
30
20
10
0
3-sec
1-min
Sep 28, 14:00
Sep 28, 16:00
Sep 28, 18:00
Sep 28, 20:00
Sep 28, 22:00
Sep 29, 00:00
Sep 29, 02:00
Sep 29, 04:00
Time (UTC)
2022
Wind Direction (deg)
360
270
180
90
0
3-sec
1-min
Sep 28, 14:00
Sep 28, 16:00
Sep 28, 18:00
Sep 28, 20:00
Sep 28, 22:00
Sep 29, 00:00
Sep 29, 02:00
Sep 29, 04:00
Time (UTC)
2022

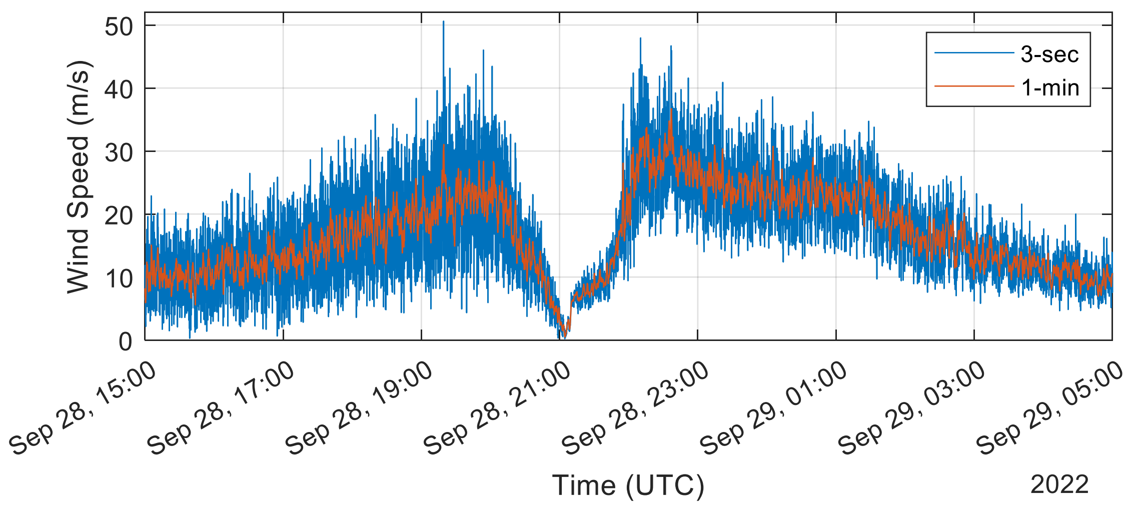

HURRICANE RESEARCH

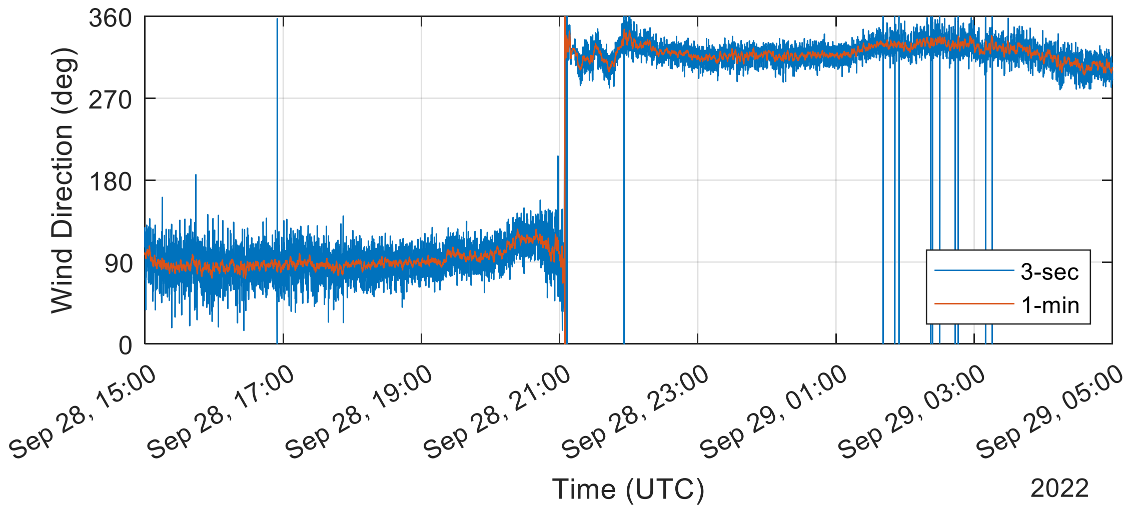
Tower T2

Latitude: 26.89584
Longitude: -82.02796
https://goo.gl/maps/KvJs6SQApVBz2sCv7
Location: US Highway 41 median

15-m RM Young Wind Monitor data, sampled at 10 Hz

- Max instantaneous wind speed: 54.5 m/s
- Max 3-sec moving average wind speed: 50.6 m/s
- Max 1-m moving average wind speed: 36.7 m/s





APPENDIX B. SUMMARY OBSERVATIONS OF BUILDING PERFORMANCE DURING HURRICANE IAN (2022)

The following content is taken from the StEER EARR (Kijewski-Correa et al. 2023), which both PIs Prevatt and Roueche contributed to in their authorship and in their editorial capacities.

Observed Performance

The following observations are listed based on preliminary review of the FAST-1 imaging, supplemented by the year built and other relevant information from public sources as needed. The area impacted by Hurricane Ian is broken down into three regions - the Barrier Islands near landfall, coastal urban regions, and inland regions. The primary focus herein is on the barrier islands and the coastal urban regions. Pictures taken during windshield assessments by FAST teams are included to support the discussion in each section, along with pre-storm imagery from the Google Maps platform and post-storm aerial imagery from NOAA where needed to provide context. Precise locations and imagery sources for all photos are provided in the Appendix. Note this complements the Media Repository compiled by the Virtual Assessment Structural Teams (VAST) and published under this same project: PRJ-3709 (Cortes et al. 2022).

4.1. Barrier Islands near Landfall (Sanibel, Pine Island, Fort Myers Beach, Bonita Beach)

The barrier islands bore the brunt of both the storm surge and high winds of Hurricane Ian; however, the hazards were not uniform. Estero Island (containing Ft. Myers Beach), Bonita Springs Beach, San Carlos Island, and Sanibel Island experienced the highest storm surge and wave impacts, but peak wind gusts were estimated to be between 100-110 mph (NIST/ARA, 2022 Figure 2.11 of PVRR). In contrast, barrier islands north of the track, such as Pine Island, Boca Grande, and Don Pedro Island, experienced minimal storm surge but were estimated to have experienced the highest wind gusts - between 120 and 130 mph. FAST-1 was able to document representative performance of structures throughout the barrier islands, and from a preliminary review of the imagery the following themes emerge:

- **The most widespread damage by far occurred in Ft. Myers Beach and was primarily tied to storm surge and wave action.** A hazard gradient was obvious in the damage patterns, with the regions with the expected strongest wave impacts near and coastward of the Coastal Construction Control line (roughly aligned with Estero Blvd in Ft. Myers Beach) correlating with the highest frequency of complete destruction. Destruction appeared to be correlated with freeboard elevation, as illustrated in Figure 4.1.

- **Coastal structures on Sanibel Island performed noticeably better from a structural perspective than those on Ft. Myers Beach,** with no observed examples of complete collapse or washout of structures except for a few buildings at the Sanibel Lighthouse. The improved performance is notable given that high water marks reported at the time of data collection are very similar between the two islands (Cortes et al., 2022). Potential causal factors for the improved performance are: (1) the greater setback of coastal buildings on Sanibel relative to Ft. Myers Beach (roughly 400 ft vs 200 ft, respectively), and (2) the abundance of vegetative features between the buildings and the coast in Sanibel Island which could have resulted in dissipation of much of the wave energy. Figure 4.2 shows a typical coastal building on Sanibel. Differences in building stock or construction practices also could be a factor. The median year of construction was 1981 for both Sanibel Island and Ft. Myers Beach / Estero Island, but construction practices may still differ between what are two distinct communities.

- **Breakaway walls appeared to perform as intended in most cases,** but it should be noted that a survivability bias is potentially present, since structures with breakaway walls that didn't perform as intended may have washed away, destroying evidence. Further study is needed. A couple examples of breakaway wall performance are illustrated in Figure 4.3.

- **In addition to direct lateral hydrodynamic loading on structures the storm surge and waves in Ft. Myers Beach produced several other effects** including sinkhole formation, significant scouring around piles and other structural members, and uplift of slabs and floor systems. Figure 4.4 illustrates some of these effects.

- **Critical facilities performed acceptably on the barrier islands,** based on what could be observed from the surface-level panoramas (illustrated in Fig. 4.5). One possible exception was the Ft. Myers Beach Fire Department District Station 31, which experienced partial wall collapse due to storm surge. This district station was constructed on grade, and approximately 500 ft from the coastline. Otherwise, from a structural perspective, both wind and storm surge performance appeared to be good., More in-depth assessments would be needed to evaluate functionality and other performance goals of these facilities.

- **Structural wind damage was rare in site-built structures,** even north of the track where peak wind estimates were highest, but there were isolated examples of structural roof failures and partial wall collapses in older residential buildings built prior to the adoption of the Florida Building Code in 2002 (Fig. 4.6).

- **RV and mobile/manufactured home parks exhibited poor performance under direct wave action and were more likely to experience wind damage than site-built structures.** Under direct wave action, homes and parks were completely washed away (Fig. 4.7). Away from the coastline, several instances of homes pushed off their unreinforced masonry pier foundations were observed due to storm surge or inland flooding, and wind damage was frequently observed, up to and including loss of the roof structure. Most of the mobile/manufactured homes with wind damage observed in the preliminary review of the surface-level panoramas only experienced damage to the building envelope.

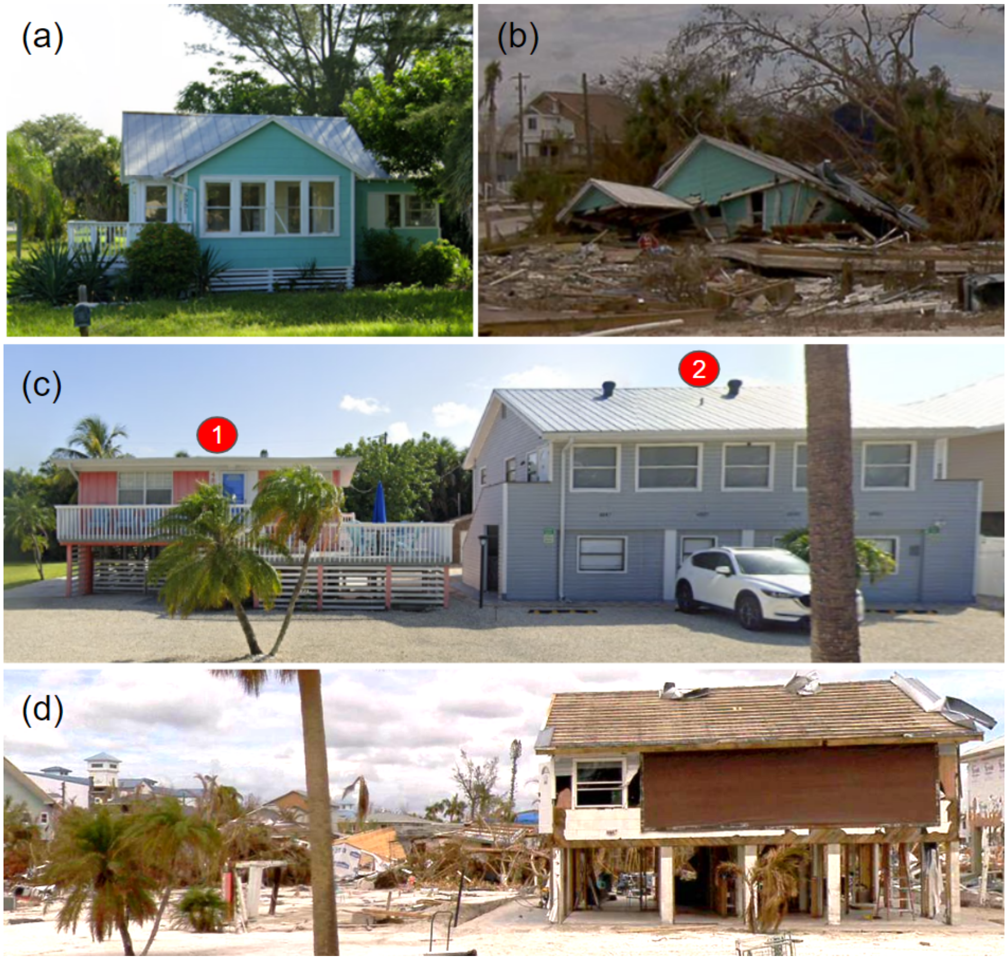


Figure 4.1. Importance of freeboard elevation to survivability, including (a) before and (b) after views of a single-family home on Estero Island constructed in 1950 that collapsed during Hurricane Ian; (c) before and (d) after views of two homes with disparate performance on Estero Island. Home (1) was constructed in 1956, while home (2) was constructed in 1950, but home (2) was elevated approximately 3 ft higher than home (1) and its breakaway walls performed as intended.

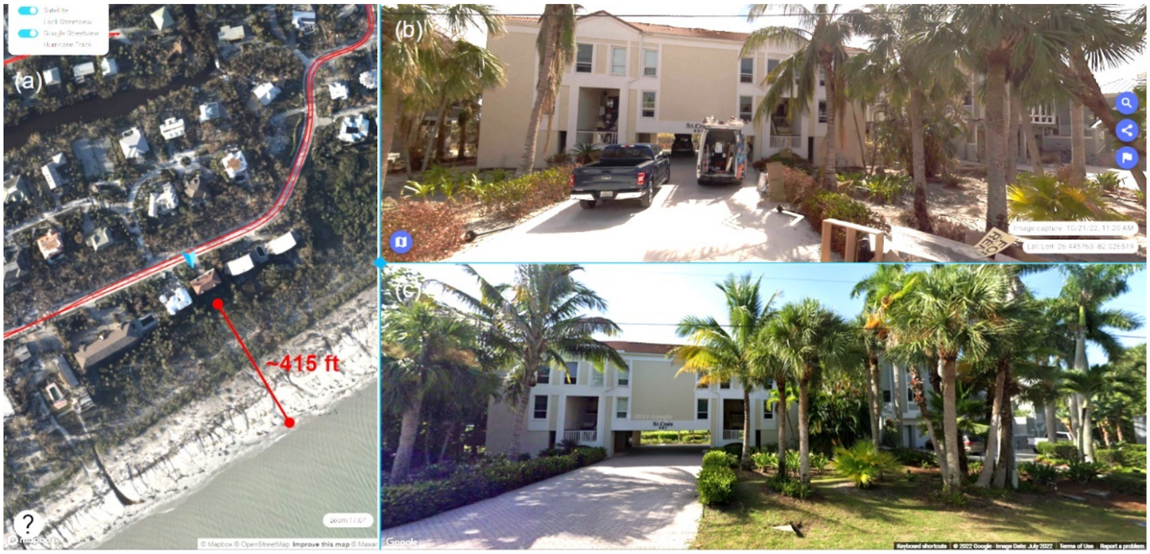


Figure 4.2. Illustrative effect of the vegetation and extended setback in Sanibel potentially mitigating surge impacts to structures. Subset (a) provides the post-storm aerial view showing a setback of approximately 415 ft from the shoreline, (b) the post-storm surface-level view, and (c) the pre-storm surface-level view.

Figure 4.3. Examples of the performance of breakaway walls during Hurricane Ian, including (a) before and (b) after views of a home on Estero Island constructed in 2000 with acceptable performance of the breakaway walls; and (c) before and (d) after views of a two-story structure with garage at ground level constructed in 2020 in which the breakaway CMU walls on the back side of the structure only partially broke away.

Figure 4.4. Examples of scour, uplift, and other surge effects on buildings during Hurricane Ian, including (a) debris transport and breakaway wall performance, (b) scouring and pavement washout, (c) scour around piers, and (d) effects of hydrodynamic uplift forces on a wood-framed floor system.

Figure 4.5. Illustrative performance of critical or cultural facilities on the barrier islands, including (a) the Ft. Myers Beach Fire Department District Station 31, constructed in 1985 with partial collapse of some walls and breaching of roll-up doors; (b) the Ft. Myers Beach Library (portion shown added in 2011) with only minor loss of metal roof cover visible (not shown); (c) Ft. Myers Beach Town Hall (constructed in 1968) with surge damage to end wall and washout below foundation; (d) Ft. Myers Fire Station No. 33 (built in 2008) with no visible signs of exterior damage; (e) Pine Island Fire Station (built in 1975) with no signs of exterior damage; and (f) Sanibel Fire Department Station 171 (built in 2005) with no visible signs of exterior damage.

Figure 4.6. Examples of poor wind performance on the barrier islands, including (a) a 3-story home constructed in 1999 with partial roof structure removal and wall collapse in the top story, (b) gable end roof structure loss in apartment buildings constructed in 1986; (c) garage door framing blown inward in a home constructed in 1967; (d) roof structure failure in one home adjacent to loss of metal roof cover in another, both of which were constructed in 1978.

Figure 4.7. Example of surge impacts on RVs and manufactured homes on Ft. Myers Beach during Hurricane Ian: (a) before oblique view of the RV park, and (b) after view of the RV park shown in (a). The red triangle in (a) approximates the location and field of view in (b).

4.2. Coastal Urban Regions (Cape Coral, Ft. Myers, Port Charlotte, Punta Gorda)

Coastal urban regions such as Cape Coral, Ft. Myers, Port Charlotte, and Punta Gorda experienced primarily high wind, flooding (both surge-induced and rain-induced), and heavy rain hazards. Missing was the wave action that contributed heavily to the damages observed in the barrier islands. Structures appear to have performed well in what was ultimately a below design-level event for wind hazards based on the preliminary wind field modeling (Cortes et al., 2022). The following summarizes some key observations taken from review of the NOAA aerial imagery and the SLP and other imagery collected by FAST-1.

- **Isolated structural wind damage was observed in Punta Gorda, Port Charlotte and surrounding regions**, primarily consisting of the loss of structural roof framing (e.g., rafters, trusses, purlins) in older construction (pre-Florida Building Code) as illustrated in Figure 4.8. Structural damage to site-built single-family homes was isolated in these areas, as a preliminary review of the FAST-1 imagery did not reveal any examples of such failures.

- **Roof cover damage was commonly observed but the extent of damage varied considerably.** The frequency and extent of damage by roof cover material type is beyond the focus of this EARR, but examples of damage were easily identified for asphalt shingle (Fig. 4.9) and clay/concrete tile (Fig. 4.10) roofs. Older asphalt shingle roofs tended to experience the most severe damage, while newer asphalt shingle roofs and tile roofs typically only exhibited the loss of a few shingles or tiles, respectively. Many non-residential buildings also showed signs of roof cover damage, including hospital facilities as highlighted in Cortes et al. (2022).

- **Municipal structures performed well, showing only minor damage to building envelope components (roofing, wall cladding)** (Fig. 4.11). For example, the Peace River Elementary School in Punta Gorda appeared essentially unscathed save for failure of metal trellis (Fig. 4.11a).

- **A few illustrative examples of significant fenestration damage were observed** (Fig. 4.12), but such damage also does not appear to be widespread.

- **Manufactured home communities' performance was generally worse than that of site-built construction, but structural damage was still not common in the coastal urban regions**. Damage primarily consisted of the loss of cladding elements, as illustrated in Figure 4.13, but structural damage was more frequently observed in some communities closer to the coast where the highest wind speeds would have been experienced (Fig. 4.13 a, b).

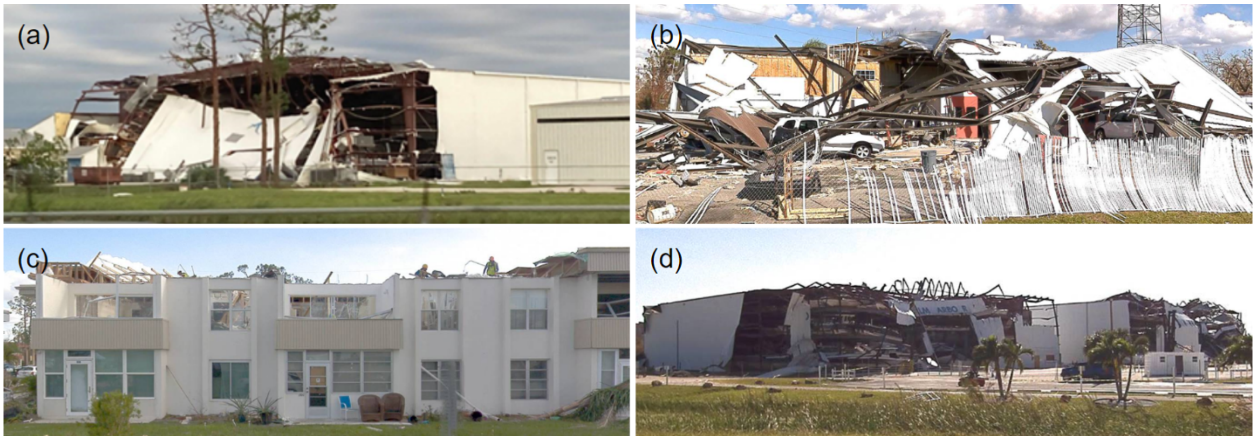


Figure 4.8. Examples of significant structural damage from Hurricane Ian, including (a) end bay failure in a metal building aircraft hangar (year built: 1996) at Punta Gorda airport, (b) collapse of an automobile maintenance garage in Grove City constructed in 1986; (c) wood roof structure failure in two-story wood-frame condominiums in Port Charlotte constructed in 1973, and (d) end bay collapses and cladding loss of two marina buildings in Cape Haze constructed in 1999.

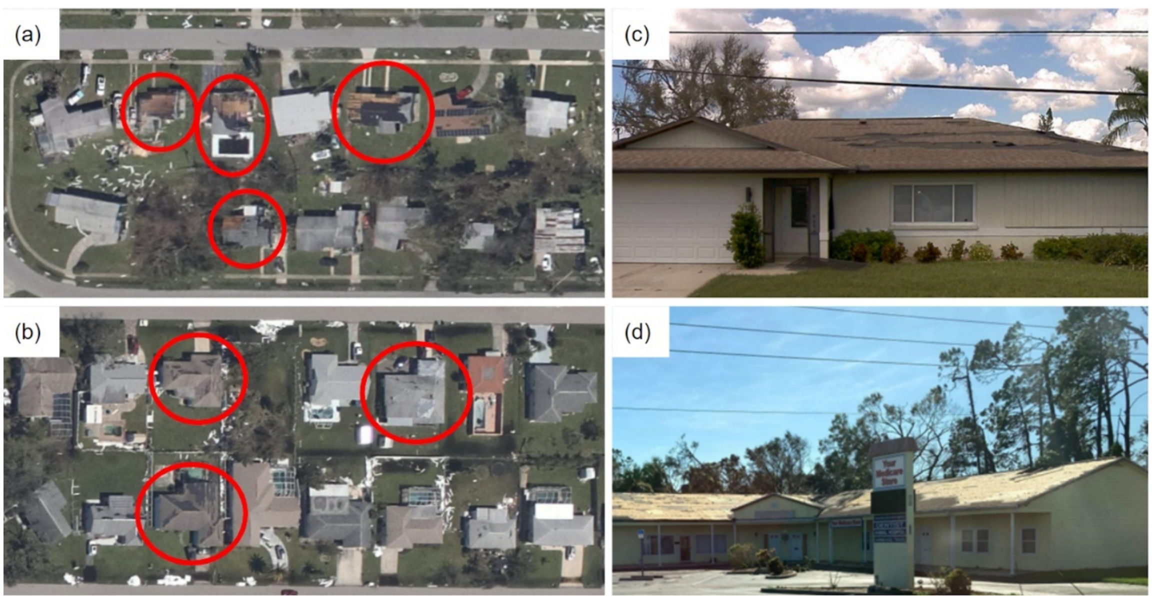


Figure 4.9. Illustrative performance of asphalt shingle and rolled membrane roofs in Port Charlotte consisting of homes constructed in the (a) 1960s with asphalt shingles and rolled roofs, (b) 1980s, (c) 1980s construction but asphalt shingle roof installed in 2005 but also (d) isolated commercial structures.

Figure 4.10. Illustrative examples of damage to tiled roofs, including (a) tile uplift (indicated by red ellipses) concentrated along the eaves of a single family home in Punta Gorda constructed in 1969; (b) loose tiles in the field and ridge regions of the roof on a condominium in Punta Gorda, FL constructed in 1989; and (c) isolated loose tiles on a roof on a multi-family residential unit also in Punta Gorda, FL constructed in 1990.

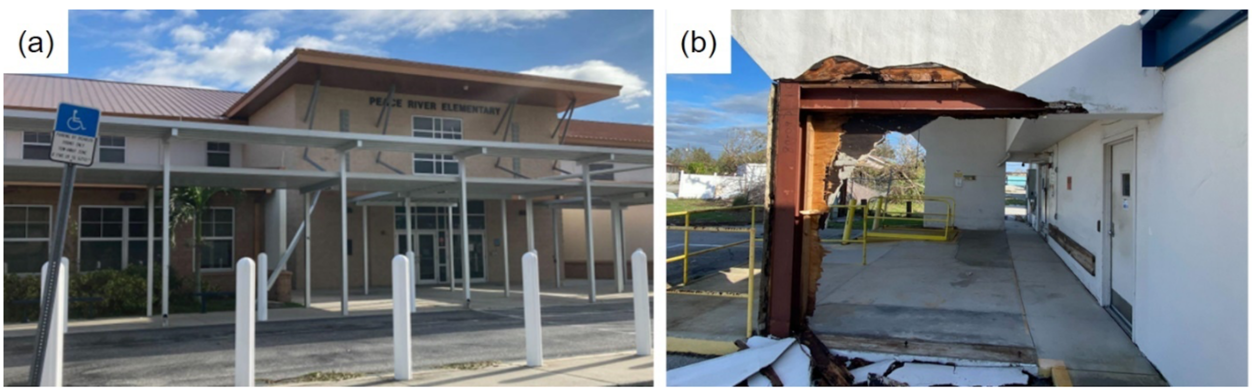


Figure 4.11. Isolated cladding loss in non-residential buildings, including (a) minor damage to flashing at Peace River Elementary School in Port Charlotte and (b) failure of exterior stucco-clad wall panel at USPS office in Port Charlotte.

Figure 4.12. Examples of isolated fenestration damage observed in the Port Charlotte area, including (a) and (b) complete loss of glass storefront in a commercial building constructed in 1973, and (c) broken windows in a 5-story commercial building constructed in 1987.

Figure 4.13. Illustrative damage to mobile/manufactured homes, including (a) aerial and (b) street-level views of structural damage to Gasparilla Mobile Estates in Placida (established in the 1970s), including loss of roof structure and wall collapses; (c) cladding damage to manufactured homes in Punta Gorda; and (d) shifted unreinforced masonry piers supporting a manufactured home subjected to storm surge on San Carlos Island.

4.3. Inland Regions

FAST-1 did not observe any significant structural damage in the inland regions during limited scouting, primarily while traveling to/from home bases and the coastal urban regions of interest.

A few illustrative photos of inland flooding and damage to transportation infrastructure captured by FAST 1.1 are shown in Figure 4.14. While Hurricane Ian caused significant impacts in these inland areas due to flooding, treefalls, and other hazards, the impacts are likely outside of the purview of StEER and are not investigated further at this time.

Figure 4.14. Photos of damage to the road infrastructure in inland regions: (a) street flooding at Exit 182 in I-75 on route to Sumter Blvd. and (b) damaged traffic lights at the intersection of City Center and Sumter Blvd. in the city of North Port.

APPENDIX C. LIST OF ATTRIBUTES AND FEATURES BEING COLLECTED IN THE DATA ENRICHMENT EFFORT.

The following provides a list and brief description of the building attributes and features being collected as part of the data enrichment effort of Task 5.1.

Features	**Descriptions**
ID	Unique identifier for each building
Latitude	GPS Latitude
Longitude	GPS Longitude
Parcel ID	Unique identifier assigned by county
Occupancy	Occupancy class of building
Address Sub Thoroughfare	Street number
Address Thoroughfare	Street name
Address Locality	City
Address Sub Admin Area	County
Address Admin Area	State
Address Postal Code	Zip Code
Year Built	Original year of construction
Number of Stories	Number of stories above ground
Elevation to LHSM	Elevation to lowest horizontal structural member in feet
Base Flood Elevation	Base flood elevation as determined by the current FEMA FIRM
CCCL Location	Location inside or outside of the Coastal Construction Control Line
Wall Cladding Type 1	Primary wall cladding type
Wall Cladding Type 1 Area	Proportion of primary wall cladding type
Wall Cladding Type 2	Secondary wall cladding type
Wall Cladding Type 2 Area	Proportion of secondary wall cladding type
Roof Cover	Roof cover type
Roof Shape	Shape of roof
Roof Slope	Slope of roof by pitch
Mean Roof Height	Average height of roof
Building Length	Maximum horizontal footprint dimension
Building Width	Minimum horizontal footprint dimension
Foundation Type	Type of foundation system
Structural System	Type of primary structural system
Breakaway Wall Performance	Whether breakaway walls are present and if so, whether they failed or not
Flood Slab Uplift	Whether floor slab uplift is observed
Debris Impact Damming	Whether debris impact or damming is present or contributed to damage
Building Collapsed or Partially Collapsed	Whether building is partially or fully collapsed
Building Shifted Off Foundation	Whether building has been displaced off its foundation
Garage Door Performance	Whether garage door is present, and performance if so
Roof Structure Damage	Percentage of roof structure damaged or missing
Roof Substrate Damage	Percentage of roof decking damaged or missing

Roof Cover Damage	Percentage of roof cover damaged or missing
Wall Structure Damage	Percentage of wall structure damaged or missing
Wall Substrate Damage	Percentage of wall sheathing damaged or missing
Wall Cover Type 1 Damage	Percentage of primary wall cover type damaged or missing
Wall Cover Type 2 Damage	Percentage of secondary wall cover type damaged or missing
Fenestration Damage	Percentage of windows or entry doors damaged or missing
Soffit Damage	Whether soffit damage is observed
Fascia Damage	Whether fascia damage is observed
Surge Damage Rating	Overall surge damage rating
Wind Damage Rating	Overall wind damage rating
Permit 1 Number	Permit number for wind mitigation related permit
Permit 1 Type	Type of wind mitigation related permit
Permit 1 Year	Year permit was closed
Permit 2 Number	Permit number for second wind mitigation related permit
Permit 2 Type	Type of wind mitigation related permit
Permit 2 Year	Year permit was closed
Peak Gust Wind Speed	Peak estimated 3-second gust wind speed in mph from the ARA wind maps
Peak Sustained Wind Speed	Peak estimated 1-minute sustained wind speed in mph from the ARA wind maps
Storm Surge Inundation	Peak storm surge inundation in ft relative to NAVD88 from high water marks