Online Damage Report

The 11th January 2014 Wind Damage and Collapse of the Brier Creek Condominiums in Brier Creek, NC

(Source: http://www.wral.com/builder-starting-over-on-storm-damaged-condos-in-brier-creek/13295582/)

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EXECUTIVE SUMMARY

This report focuses on the wind damage to the Brier Creek Condominiums near Raleigh, North Carolina. On January 11 2014, two structures, which were under construction at the time of the failure, experienced moderately high wind gusts and collapsed. The failure of the building was captured by an amateur photographer and viewed on CNN and other news outlets on 12 January 2014. A CNN Video of the failure captured by Ed Braz can be found here. A probable failure sequence is postulated and possible causes of the building failure are presented. The purpose of this rapid, preliminary assessment is to stimulate discussion among engineers, meteorologists, builders and the wider community regarding the wind resistance required for light-framed wood structures. Our ultimate hope is that such discussion is leading to improved understanding and widespread application of appropriate engineering systems to mitigate wind damage to buildings.

BACKGROUND

On January 11, 2014 a strong midlevel trough moved through the southeastern states, stretching from north Florida to Delaware, bringing with it significant rainfall and straightline winds. The SPC outlook for the day as of 3pm EST is provided in Figure 1. The primary risk was the widespread straightline winds in advance of the approaching system, although there was a slight risk of tornadoes. The outlook was accurate, with significant wind speeds experienced across the region, with wind speeds as high as 86 mph reported at the Raleigh-Durham International airport.

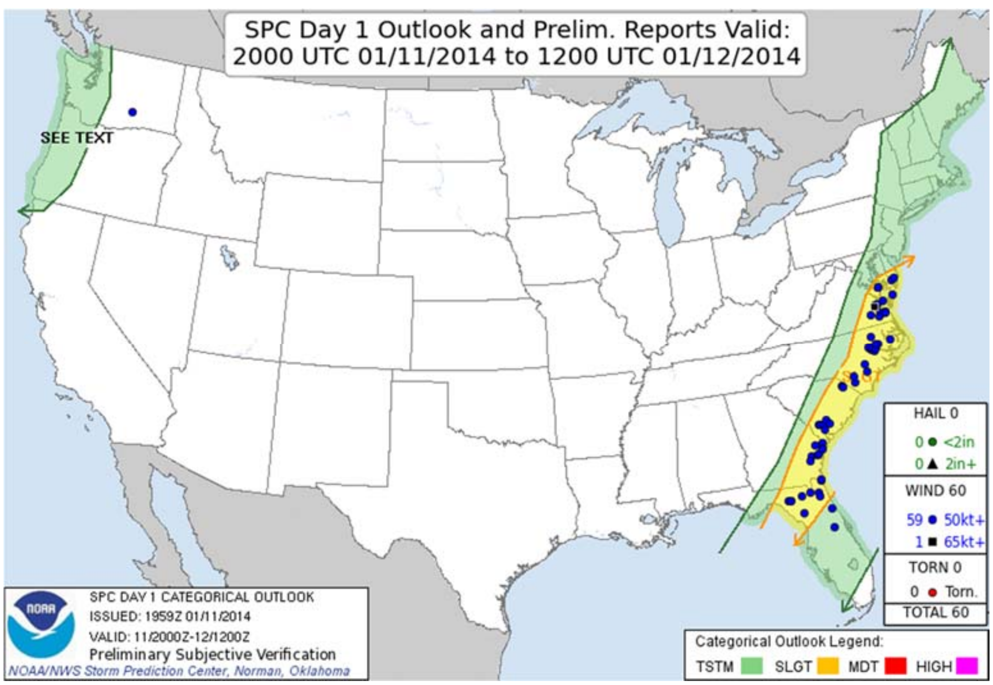

Figure 1: NWS severe weather outlook with preliminary verification map overlaid

SUMMARY OF REPORTED DAMAGE

Although no tornadoes were confirmed, the straightline winds caused varying amounts of damage throughout the affected regions. A fatality occurred when a tree limb fell on a pedestrian in Wake County, NC. The heaviest damage was to several condominium structures under construction in Bier

Creek, NC, just north of Raleigh. Elsewhere, the damage primarily consisted of uprooted trees, with several cases of trees falling onto houses and causing damage. This report focuses on the wind damage to the Brier Creek Condominiums.

DAMAGE TO BRIER CREEK CONDOMINIUMS

Brier Creek Condominium is located in Wake County, NC, within a large residential subdivision, known as The Exchange at Brier Creek. The Exchange (and the damaged condos themselves) are located approximately one mile away from the Raleigh Durham International Airport (Figure 2). Aerial photograph show the approximate location of the Brier Creek Condominium on Bruckhaus Road that was damaged, Figure 3 (note the photo was taken before construction began). The structures were 3-storeyed wood-framed buildings that had carports on the ground floor and two occupied floors above it. The long dimension of the building was oriented in a general east-to-west direction.

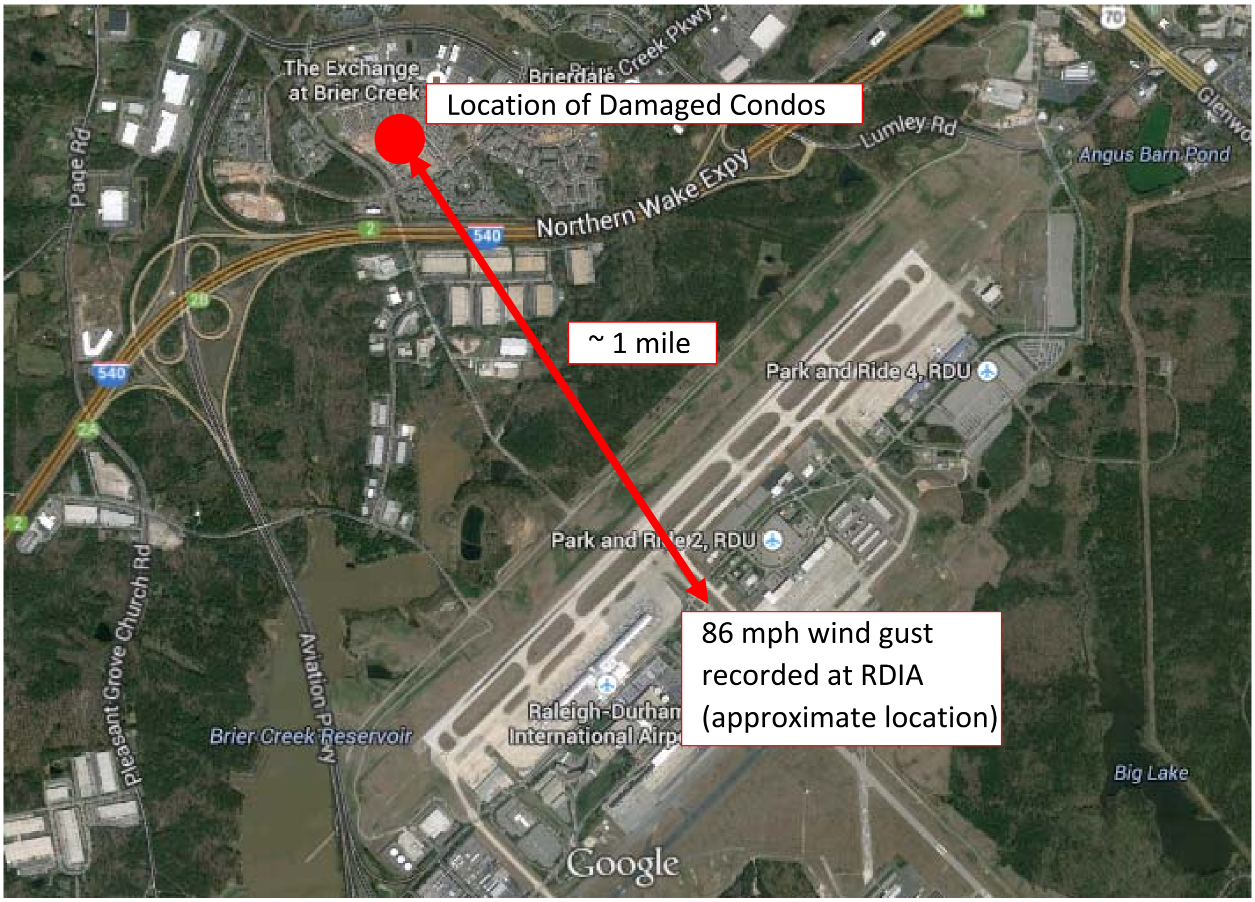

Figure 2: Location of damaged condominiums relative to wind gust recorded at Raleigh-Durham International Airport

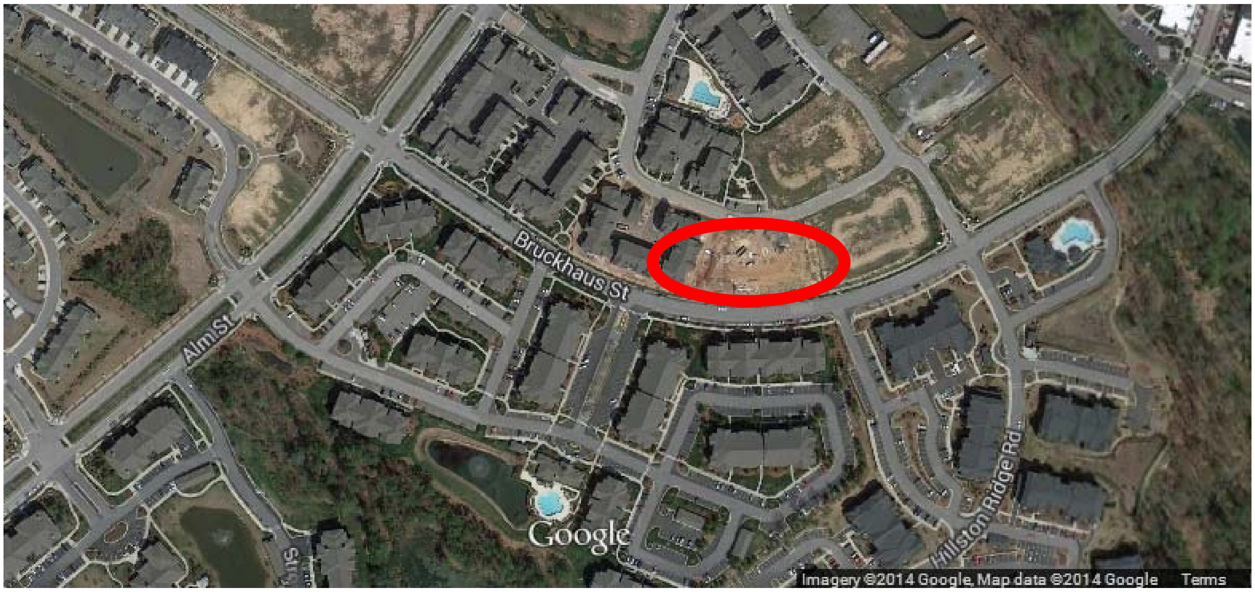

Figure 3: Specific location of damaged condominiums indicated by red ellipse

Wind Velocity

The peak wind gust of 86 mph was recorded at the nearby Raleigh-Durham Airport weather station, KRDU, and the wind direction was from the south to southwest. The graph in Figure 4 was obtained from the National Weather Service's Daily Summary Report and it summarizes the hourly wind observations - wind direction, hourly wind speed;2-minute averaging time, and gust wind speed; 3-second averaging time, taken at the KRDU station during the storm. The strongest winds appear to have impacted the south (long) face of the building at around 2:24 pm on 11 January 2014. The video of the failure was likely taken from an existing condominium unit located just the northwest of the failed structure.

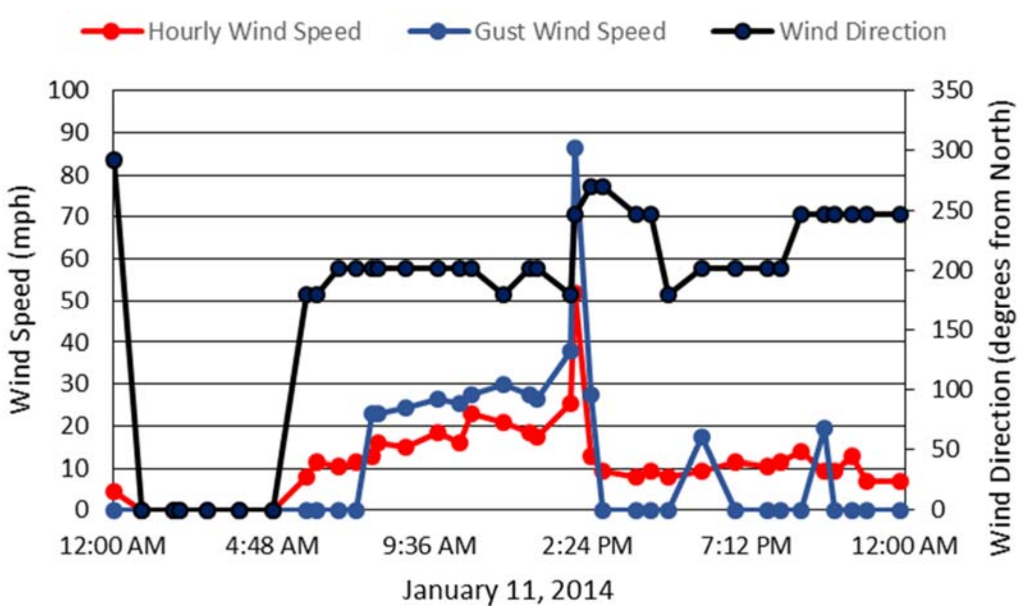

Figure 4: Wind Velocity observations from the Raleigh-Durham International airport weather station,

The airport weather station is located approximately 1 mile southeast of the damaged condominium in relatively open terrain (assessed from the aerial photographs) and so it is reasonable to expect the wind speed at the condominium would be similar to what was measured at the airport.

Figure 5: Location of collapsed condos with respect to captured video and approaching wind angle

At this time few details are available about the collapse.   Several pictures were posted to Twitter and these are reproduced here in Figures 6-10. There is a Toll Brothers sign in Figure 10.

Figure 6: Courtesy of Kristin Ruffin (@kleighru) from WRAL

Figure 7: Courtesy of Justin Quesinberry (@JustinQberry). Note that the buildings collapsed forward onto the empty slab. The slab in the foreground was not part of the damaged buildings. The condos in the background likely sheltered the collapsed condos to some degree from the approaching wind.

Figure 8: Courtesy of Lauren Amos Designs (@LADjewelry)

Figure 9: Courtesy of Ricky A. Richardson (@Rickshots)

Figure 10: Courtesy of Carly Swanson (@CarlyTWCNews)

Possible Sequence of Failure

The failure of these structures while under construction provide an interesting opportunity to evaluate the construction standards in use. With a design wind speed of 100 mph per ASCE 7-05 (still in use by 2012 North Carolina Building code), the condos failed below design, despite appearing to have the majority of the structural components already installed.

Our assessment is made solely on basis of videos and still photographs available on the internet and WITHOUT DETAILED KNOWLEDGE OF THE EXACT STAGE OF CONSTRUCTION. The authors have not made any site visits or attempted to contact owners regarding the construction. The purpose of our report is to present the available information to the scientific and engineering community to stimulate discussion as to best practice approaches to residential construction. No doubt, detailed forensic studies will be done that would identify causes of this building failure.

- The collapsed buildings appeared to consist of two, 3-story gable-roofed condominium units and a 2-story, gable roof condominium units. The ground level serves as a carport, while the two upper floors were living spaces. We did not see a view of the south facing wall of these units.
- No exterior or interior wall cladding (except vapor barrier) or roof covering materials appear to be installed.
- Light-framed wood structural framing and sheathing (OSB) were installed in all three floors in 3-story block, while the north wall of the 2-story condo was framed but it did not have sheathing installed.
- The minimum (code-stipulated) anchorage of the wood-frame walls to the concrete foundation would be ½" dia. anchor bolts at 6 ft. on center per the North Carolina building code. Anchor bolts are visible in Figure 6 (above), installed in the adjacent bare concrete ground floor slab located just north of the collapsed structures.
- There are no windows or doors installed in openings in any of the walls of the collapsed structures..
- Failure initiated in the bottom story of the fully-sheathed 3-story condominium. The building rocked forward (towards the north) exhibiting similar behavior similar to the soft-story building failures that commonly occur to residential structures in earthquake-prone regions.

A video of a soft-story collapse during experimental testing by NEES can be seen through the following link: http://www.youtube.com/watch?v=25hCATGKSbI. Soft-story buildings are generally wood-frame buildings, which have an open ground floor area (often for parking) with few interior partitions, and with regular residential living spaces on the upper floors. The issue with such structures is that the because of the large openings and open interior spaces of the ground floor, the ground floor level is significantly less stiff than the upper floors and it has less lateral resistance than the top two floors. When large lateral loads are placed on the structure, the bottom floor begins to deflect, the deflections activate P-Δ effects, and without any external bracing, collapse of the entire structure ensues.

This appears to be the cause of failure in these condos. Careful inspection of the video reveals the following failure sequence (stills are taken from video of condo collapse provided above):

1. Significantly large lateral displacement occurs at top of first floor of the 3-story condo. Limited relative displacement observed between second and third floor levels (i.e. top 2 floors undergo rigid body motion).

2. As lateral displacement increases collapse mechanism initiates. At the ground floor level, wood sheathing (circled) displaces independently (and without fracturing) of the 2 by 4 wood framing. The displaced sheathing appears undamaged at the corner.

3. First floor level collapses, displacing the second, third stories and roof in rigid body motion. Additional wood wall sheathing appears to peel off of wall framing nearly intact (circled), which further reduces shear capacity of the N-S wall. Question: if wall sheathing fully or properly attached to framing, why does it fail in this manner.

4. Failure of adjacent 2-story structure begins, possibly due to instability caused by failure of 3-story. Soft-story failure occurs at first floor level. Second floor and roof level appear to undergo some rotation as it fails.

5. With the collapse of the bottom "soft" stories, the entire structures collapse on top of them and both condos are completely destroyed. Few observations of fractured wall sheathing or framing members

Causes of Failure

1. With the failure initiating in the bottom story of the sheathed condo, it is possible that the cause of the failure was unfinished or improper nailing of the bottom story sheathing along the side (E-W) shear walls.
2. It is also possible that the shared bottom story side (E-W) wall, between two units may not have been sheathed at the time of this wind event, in which case it would have lacked any shear capacity to transfer the applied lateral loads due to the high winds. Figure 6 appears to confirm this assumption, as it shows wall framing but no wall sheathing between the condominium units.

Figure 6 reprinted. Note the absence of wall sheathing at the North-South demising wall between adjacent buildings highlighted by the red rectangle.

Wall Requirements from North Carolina Building Code

The North Carolina residential building code specifies certain requirements for exterior wall sheathing as shown in Figure 11. For a wind speed of 100 mph in Exposure C, the code required 8d common nails with a maximum spacing of 6" on edges and 12" in the field.

TABLE R602.3(3)
REQUIREMENTS FOR WOOD STRUCTURAL PANEL WALL SHEATHING USED TO RESIST WIND PRESSURES[a,b,c]

MINIMUM NAIL		MINIMUM WOOD STRUCTURAL PANEL SPAN RATING	MINIMUM NOMINAL PANEL THICKNESS (inches)	MAXIMUM WALL STUD SPACING (inches)	PANEL NAIL SPACING		MAXIMUM WIND SPEED (mph)		
							Wind exposure category		
Size	Penetration (inches)				Edges (inches o.c.)	Field (inches o.c.)	B	C	D
6d Common (2.0" × 0.113")	1.5	24/0	3/8	16	6	12	110	90	85
8d Common (2.5" × 0.131")	1.75	24/16	7/16	16	6	12	130	110	105
				24	6	12	110	90	85

For SI: 1 inch = 25.4 mm, 1 mile per hour = 0.447 m/s.

a. Panel strength axis parallel or perpendicular to supports. Three-ply plywood sheathing with studs spaced more than 16 inches on center shall be applied with panel strength axis perpendicular to supports.

b. Table is based on wind pressures acting toward and away from building surfaces per Section R301.2. Lateral bracing requirements shall be in accordance with Section R602.10.

c. Wood Structural Panels with span ratings of Wall-16 or Wall-24 shall be permitted as an alternate to panels with a 24/0 span rating. Plywood siding rated 16 oc or 24 oc shall be permitted as an alternate to panels with a 24/16 span rating. Wall-16 and Plywood siding 16 oc shall be used with studs spaced a maximum of 16 inches on center.

Figure 11: Requirements for exterior sheathing size and attachment schedule from North Carolina 2012 Residential Building code

Section R602.10 specifies detailed requirements for lateral bracing of walls. It is unclear whether these requirements were fully followed or not unless more information is provided. Further, it is not clear whether the intermediate wall between the adjacent units would be classified as an interior or exterior wall.

CONCLUSIONS

The maximum 3-second gust wind speed recorded during the 11 January 2014 storm that initiated the dramatic collapse of the under-construction Brier Condominium Building was 86 mph. This wind speed was recorded about one mile away at the KDRU weather station at the Raleigh-Durham International Airport. The ASCE 7-05 design wind speed for this location for a Category II building is 100 mph (3-second gust wind speed), which was adopted in the 2012 North Carolina Building Code. Thus, the actual wind load that initiated this failure is estimated at less than 75% of design wind loads for Wake County, NC structures.

Two condominium buildings failed under impact of a southerly wind gust that impacted the buildings from a perpendicular direction to the building's south-facing, exterior wall. From the video and photographs available we believe that one (3-story) condo was fully framed and had exterior wood sheathing on both its north and south exterior faces. No fenestration was installed in the openings. The other failed condo was also fully framed but it had wood sheathing only on the south facing exterior wall. Evidence suggests that the demising (north-to-south) walls between condominium units may not have had wood sheathing at the time of wind event, and this may have caused the buildings to fail.

If the building were fully constructed, wind load from a strong southerly wind would typically produce positive pressure on the south-facing exterior wall that would have to be transferred through shear walls along the short (north-to-south) demising walls to the ground. Without the sheathing on these demising walls, the shear capacity would be near zero. A soft-story failure mechanism is also observed, in which the first floor walls first crumple and producing large rigid body displacement of the upper stories and roof.

Very little fracture of wood framing members or wood sheathing panels were observed in the video and photographs (whole sheets of OSB appeared to pop off the wood framing undamaged), suggesting the brittle failures are occurring at the mechanical connections between sheathing and framing elements dominated the failure mechanisms. Construction sequencing may be an important element of this forthcoming investigation, as is the question of strength and shear capacity of the wall sheathing fasteners.

ACKNOWLEDGEMENTS

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ABOUT THE PI

David O. Prevatt is an Associate Professor of Civil & Coastal Engineering, in the School of Sustainable Infrastructure & Environment, University of Florida, Gainesville, FL. He is a registered professional engineer registered in Massachusetts and in Trinidad and Tobago.

Peer-Reviewed Publications

Prevatt, D. O., Coulbourne, B., Graettinger, A., Pei, S., Gupta, R., and Grau, D. (2013). "Tornado of May 22, 2011 – Structural Damage Survey and Case for Tornado-Resilient Building Codes", 47 p. ASCE/Structural Engineering Institute, Reston, VA.

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About the Wind Hazard Damage Assessment Team

This report was prepared from online sources by University of Florida civil engineering students in Prof. David O. Prevatt's Research Group. The study is done in parallel to our experimental research seeking to understand and quantify the strength of tornadoes and their impact on vulnerable wood-framed residential structures. Compilation of this information is part of student learning objectives in forensic engineering and post-disaster damage investigation.

The students gathered the information from reliable online sources, such as the National Weather Service, Accuweather, the US Census Bureau and the national media. Photographs were also obtained from publicly available Twitter feeds.

Please visit our website, http://windhazard.davidoprevatt.com, for additional information, and to download previous damage reports, and filed survey results conducted by our group. Dr. Prevatt and his colleagues have published several papers on recent violent tornadoes, that stuck Tuscaloosa, AL, Joplin, MO, and Moore, OK. His group has also inspected damaged structures and compiled reports on tornadoes that occur in Florida. Information is also available on the research at www.davidoprevatt.com. Your questions and comments on any aspects of our work are most welcome. Please direct your enquiries to NSF Graduate Research Fellow and PhD Graduate Student, Mr. David B. Roueche, who can be reached at david.roueche@ufl.edu. Mr. Jeandona (JD) Doreste, is a civil engineering undergraduate student at UF and Webmaster of the Wind Hazard Damage Assessment Team site. JD is actively recruiting other UF students to join the team, and he can be reached at jdoreste1@ufl.edu.

The Wind Hazard Damage Assessment Team was created through support from the NSF Award #1150975. Its mission is to train university students interested in building construction, engineering and architecture in the forensic engineering and techniques for post-hazard damage surveys and data collection. The team has surveyed damage after several Florida tornadoes and continuously monitors the prevalence of tornadoes worldwide. Ultimately the Damage Assessment Team hopes to inspire upcoming engineers and building professionals in hopes to change the paradigm of widespread catastrophic damage to houses in tornadoes and other extreme wind events.