HOMES LIKE THIS ONE IN FAIRFIELD THAT WERE ELEVATED AFTER SUPERSTORM SANDY IN 2012 MAY HAVE INCREASED VULNERABILITY TO WIND. LAURA RUOCCO-PULIE, RIGHT, CIVIL ENGINEER FOR THE TOWN, COLLABORATED ON A PROJECT WITH UCONN PROF. WEI ZHANG TO ASSESS THE WIND LOAD RISK. PHOTOS: NANCY BALCOM

Solving an engineering conundrum: as coastal homes get elevated, new research looks at whether the vulnerability to wind damage is increasing

By Nancy Balcom

Among the many images of devastation wrought by hurricanes in recent years, one stands out in my mind. It's of a beachfront home on a stretch of Mexico Beach, Fla., that remained standing and largely undamaged after Hurricane Michael devastated the Florida Panhandle in 2018. It was a new home, constructed to withstand whatever Mother Nature could throw at it in a tantrum of storm surge, water and wind. Among the piles of wrecked homes and lives, it was a symbol of resilience, one that I hope we will see more frequently in coastal communities following hurricane events.

Hurricane Irene and Superstorm Sandy are Connecticut's most recent reminders of the tremendous destruction that can be caused by coastal storms. In New Haven and Fairfield counties, 4,000 homes were destroyed and the resulting damages tallied $360 million. As coastal communities and residents look warily to the next big storm, they are starting to take steps to prevent or mitigate future losses. For some, these steps include rebuilding and elevating single-family homes above new higher flood level projections from the Federal Emergency Management Agency (FEMA).

"The risk of flood damage is typically greater than the risk of wind damage in Connecticut," said Wei Zhang, an assistant professor of civil and environmental engineering at the University of Connecticut. "But single-family homes in New England tend to have multiple stories and steep roofs which increase the wind pressure [load] on the structure." He began to wonder whether elevating an existing house to increase its resilience to flood hazards might inadvertently increase its vulnerability to wind.

With funding from Connecticut Sea Grant and in collaboration with the Towns of Milford and Fairfield, Zhang and his team set out to investigate this question: Does elevating existing homes above the 100-year or 500-year flood line to reduce their vulnerability to storm surge and flooding make them more susceptible to the ravages of high winds? This could be the proverbial out-of-the-frying-pan-and-into-the-fire scenario or, in this case, out of the water and into the wind.

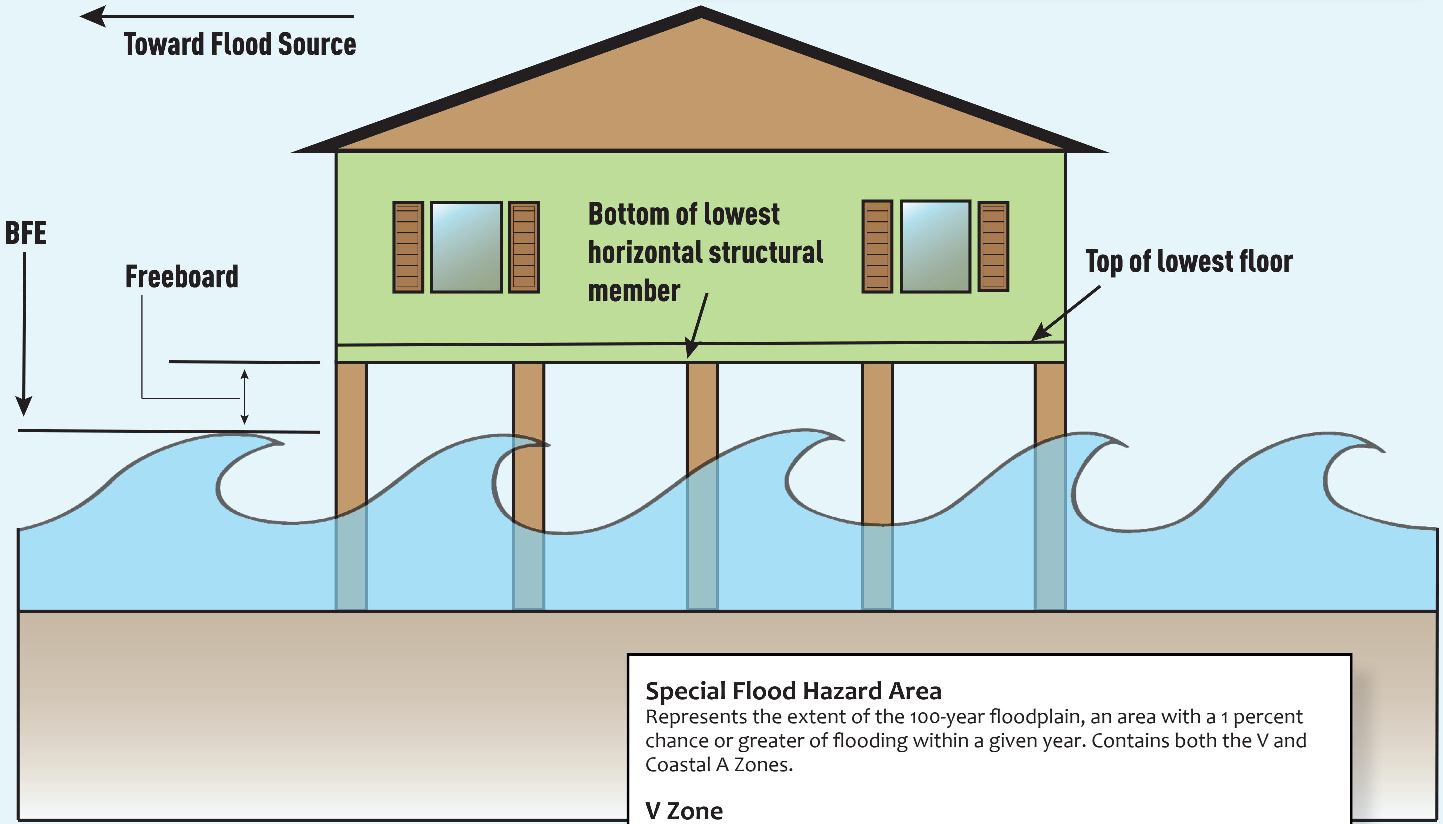
"The concern is that newly elevated homes that once stood two or three stories tall are now standing three or four stories tall, and exposed to greater wind loads," said Laura Ruocco-Pulie, civil engineer with the Town of Fairfield and project collaborator. "While owners must elevate their existing homes to meet flood insurance

Prof. Wei Zhang, third from the right, used this home being elevated in Fairfield as part of his research project. With him are several UConn graduate students, including three who worked on the project. Photo courtesy of Wei Zhang

RECOMMENDED CONSTRUCTION IN COASTAL A AND V ZONES

Base Flood Elevation: The minimum elevation to which floodwater is anticipated to rise during a flood that has a 1 percent chance of occurring in any given year. It is the regulatory requirement for the elevation of structures. The relationship between the BFE and a structure's elevation determines the flood insurance premium.

Freeboard: the additional height that a house is elevated above the Base Flood Elevation. It compensates for the uncertainties in determining flood elevations, provides an increased level of flood protection and reduces flood insurance premiums.



Special Flood Hazard Area
Represents the extent of the 100-year floodplain, an area with a 1 percent chance or greater of flooding within a given year. Contains both the V and Coastal A Zones.

V Zone
Homes closest to water and in the Coastal High Hazard Zone must be:

- able to withstand high-velocity wave heights of 3 feet or more
- constructed on a pier/pile foundation system
- adequately anchored to the foundation
- elevated so that the bottom of the lowest horizontal structural member is 1 foot or more above the designated Base Flood Elevation (freeboard)
- insured for floods

Coastal A Zone
Homes in the Coastal A Zone (landward of V Zone, not within Coastal High Hazard Zone) must be:

- able to withstand wave heights of 1.5 - 3 feet
- elevated so that the top of the lowest floor is 1 foot or more above the designated Base Flood Elevation (freeboard)
- insured for floods

Graphic modified from the FEMA Coastal Construction Manual

requirements, current state building codes do not require them to retrofit their roofs at the same time, unless a significant amount of renovation is going on. So they could lose their roof to high winds."

Ruocco-Pulie explained that all new homes built within areas covered by FEMA Flood Insurance Rate Maps must be constructed to minimize the effects of both flood and wind hazards. FEMA designates Special Flood Hazard Areas with two primary flood hazard zone classifications – V and A. Generally, Zone V covers the part of the coastline that is directly exposed to the strongest wave action from storms and is considered a Coastal High Hazard Area. Coastal Zone A is farther inland than Zone V, where the main source of damage is flooding brought by coastal storms (see diagram above).

A home built within the V zone must be able to withstand a three-foot wave height. The bottom lowest horizontal structural brace of the house must be at or above the Base Flood Elevation (the expected minimum height of a flood in a storm with a 1 percent chance of occurring in a given year). In Fairfield this elevation ranges from 13 to 15 feet. With added freeboard (open space between the ground and the first floor), this horizontal structural brace might be 14 to 17 feet off the ground.

A home built in the Coastal A zone, farther from the water's edge, must be elevated 10 to 11 feet in Fairfield.

"Some homes, depending on the type of funding used to elevate the structures, are required to be elevated to the 500-year flood elevation, which is 25 percent higher than the 100-year level," said Ruocco-Pulie. "These homes really stand out."

These requirements should help minimize the damage to new homes from wind and water loads. However, an owner elevating an existing home above FEMA's prescribed base flood elevation, without undertaking significant renovation, may not realize that failure to retrofit the roof at the same time could mean increased exposure to wind loads.

Could certain structural configurations either increase or reduce vulnerability to stronger wind pressure? Zhang, his colleague Christine Kirchhoff and five graduate students began to tease out some answers, assisted by Fairfield's Ruocco-Pulie and her counterparts from the Town of Milford.

"The challenging question is, 'Can we use science to understand the interactions of natural hazards, building structures and community residents?'" asked Zhang.

This was not just an engineering problem but also a people problem.

Kirchhoff is an assistant professor in the same department as Zhang. Her background is somewhat unusual, blending civil engineering with social science. Kirchhoff uses her training to determine how to engage stakeholders effectively. This could mean collaborating with town officials, water managers, planners and farmers to generate information related to water management and infrastructure that is needed for sound decision-making. They learn together and build trust along the way.

Christine Kirchhoff, assistant professor of civil and environmental engineering at UConn, helped engage town officials and residents of Fairfield and Milford on the project. Photo: Nancy Balcom

"This project involved a different set of stakeholders than I normally work with," she said. "But the same principles I've learned over many years were applicable to this project. We discussed ways to engage town officials and community residents in a meaningful way, and what kinds of (informational) outputs might be most useful."

The research team toured storm-affected areas in Fairfield and Milford, met with town engineers and examined homes undergoing elevation. One way they connected with residents was through an interactive display at a local Earth Day celebration. Using fans to simulate wind, model houses of different types were then exposed to the "wind" to demonstrate the potential damage that could result.

> 'Can we use science to understand the interactions of natural hazards, building structures and community residents?'
>
> – Prof. Wei Zhang

I met with Zhang in his office as he was finishing the final report that he plans to share with his collaborating towns. As he sat at his computer scrolling through the extensive file, I found the array of acronyms, colorful graphs and figures, data tables, formulas and GIS-generated database layers rather intimidating at first. But as he patiently took me through the report step by step, those bewildering contents began to make sense. I was able to develop both an appreciation for the complexity involved and a basic understanding of the overall results.

Using a database of more than 2000 residential structures from the databases for Milford and Fairfield, the research team identified several parameters – such as year built, number of stories, type of roof, footing size and building materials used – that enabled them to categorize the houses into three representative groups – those built in the 1930s, the 1960s and the 1990s. (You could also think of them as colonial, cape and "McMansion" styles.) The researchers used these building groups, with three elevated and non-elevated prototypes for each, as an approximate representation of all single-family homes in coastal Fairfield and Milford.

Simulations were run on three elevated and three non-elevated homes in each building group to analyze the vulnerability of the seaward and non-seaward walls and roofs to different combinations of wind (70 mph-tropical storm; 120 mph-Category 3 hurricane; or 150 mph-Category 5 hurricane) and flood level (10-year, 100-year or 500-year). For the elevated prototypes, the researchers assumed concrete piles and steel girders were used to elevate each of the homes.

"We assessed the amount of damage based on three types of structural failure," said Zhang, "and used the results of the vulnerability

Two homes in Fairfield illustrate the contrast between those elevated after Superstorm Sandy, like the one at the left, and those that were not, like the one at the right. Photo: Nancy Balcom.

analyses to generate a series of resilience maps.”

The maps, he said, “show the anticipated damage to elevated and non-elevated houses in Fairfield and Milford that might be expected under different ‘what if’ wind and flood hazard scenarios.”

Overall, while wind damage was not shown to be as significant as previously assumed as compared to water damage, under certain scenarios, it had the potential to be very destructive.

What do they hope will result from this work?

“Over the short term we hope this provides some basic information on how homes in flood hazard zones in Fairfield and Milford might perform under different natural hazard scenarios,” Zhang said. “For the longer term, we hope to demonstrate to all communities that it is possible to integrate knowledge and ideas from scientists, engineers and community residents to systematically enhance community resilience. By sharing these results beyond Fairfield and Milford, we can help other coastal towns realize that something can be done to help improve their resilience.”

Kirchhoff added, “In time, I would expect policy changes, like adjusting building codes or better building materials, to emerge that help protect people and property.”

Ruocco-Pulie agreed.

“I hope that the state building code is changed, so that when any existing home must be elevated, the roof must be retrofitted at the same time to increase its ability to withstand wind effects,” she said.

If that happens, more coastal Connecticut homes could be left standing as beacons of resilience in the aftermath of the next great storm. Let us hope that becomes the reality.

This aerial photo taken by the Civil Air Patrol after Superstorm Sandy shows destruction to homes along the coast in Fairfield.

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