RESEARCH ROAD MAP

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The WHIP Center's mission is to pursue research of interest to industry and government agencies to enhance the resiliency of buildings and infrastructure to extreme windstorms such as hurricanes and tornadoes.

Contents

Wind Hazard and Infrastructure Performance (WHIP)

An NSF I/UCRC

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RATIONALE

Every year the United States is impacted by several wind hazards including hurricanes, tornadoes, and thunderstorms. As a result, buildings and infrastructure such as power, communication, transportation, and water systems suffer great damages causing fatalities and injuries and extensive property losses. According to Property Claim Services, U.S. insured catastrophe losses between 1997 and 2016 were over $421 billion, a total that translates to $21 billion in annual insured losses. Almost 80% of these insured losses are caused by windstorm events. The total loss to the country due to wind hazards is almost twice the insured losses. Future losses from windstorms are likely to increase because of the growing population in hazard-prone regions, aging infrastructure, and changing climate.

Inflation-Adjusted U.S. Insured Catastrophe Losses By Cause Of Loss, 1997-2016
(2016 $ billions)

Events including tornadoes (2)	$168.1	39.9%
Hurricanes and tropical storms	161.1	38.2
Other wind/hail/flood	29.7	7.1
Winter storms	28.2	6.7
Terrorism	25.0	5.9
Fires (3)	8.4	2.0
Other (4)	0.8	0.2
Total	**$421.2**	**100.0%**

Source: The Property Claim Services® (PCS®) unit of ISO®, a Verisk Analytics® company.

Unless focused research, development and implementation in resiliency in infrastructure is pursued, the property losses will continue to increase. Protecting homeowners, businesses, and communities from wind hazards involves stakeholders across many geographical boundaries and industry sectors. Therefore, the established *NSF I/UCRC WHIP* adopts a broad-based approach, and is aimed at serving members in the industries of insurance and construction. The construction industry is defined broadly as the industry that designs, engineers, constructs, manages and maintains buildings and infrastructure.

The insurance industry protects the assets of its policyholders by transferring risk from an individual or business to an insurance company. In addition to private insurers are the government's natural catastrophe insurance programs which have filled gaps in the private insurance markets and helped to limit disaster relief payments. Since the price of property insurance is affected by the annual expected loss and the cost of diversifying the risk of catastrophic losses, one of the key objectives of an insurer is to set the premium to a proper level allowing companies to be profitable, competitive, and able to pay claims and expenses as they occur. Reducing damages to insured properties has a beneficial impact to the insurance industry.

Commercial construction includes commercial, and institutional buildings along with civil infrastructures such as transmission lines, telecommunication facilities, etc., while residential construction includes multi-family housing and single-family homes. The number of people involved in construction industry in 2016 was 8.6 million in the U.S., and had spending of about $1,200 billion. However, U.S. contractors, architects, and engineers invested less than 0.05 percent in R&D as a group, mainly because of intense price competition and few mechanisms to facilitate joint funding of research that will yield distinct benefits to the participating firms. The WHIP Center provides an avenue by which the construction industry (broadly speaking) can gain leverage of investment by NSF, expertise and facilities of academic institutions, and collaboration with other companies to enhance resiliency products in this competitive market.

RESEARCH THEMES and TOPICS

Wind Hazard Assessment

Estimation of wind hazard for a community or a location and understanding of wind speeds and turbulence in hurricanes, tornadoes, and other extreme wind events within the boundary layer are part of research agenda. Field measurements and statistical analyses are pursued to obtain results that help industry partners.

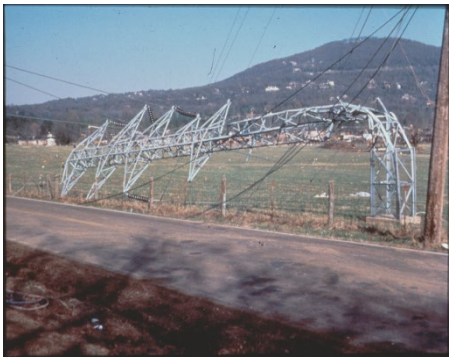
- Hurricane wind field derived from Doppler radars.
- Climate change that will result in to sea-level rise and potentially stronger windstorms
- Rate proximity of risk factors (e.g. trees) surrounding a building using satellites and drones.

Vulnerability of Buildings and Infrastructure

Vulnerability is a function of wind hazard exposure and robustness of the building and infrastructure such as transmission lines. Development of damage probabilities (fragility curves) in different type of windstorms (e.g. tornado, hurricane, downburst) for a variety of buildings and infrastructure systems will assist in improving estimation of vulnerability of the built environment.

- Shear force on roof materials, different geometries, installation defects, and aging conditions.
- Performance of PV roofing systems and effect of PV installation on roofs.
- Fundamental understanding of how aging affects the vulnerability of a structure.
- Wind-driven rain (WDR) related research.
- Wind and rain performance of soffits.
- Building performance subsequent to wind events.
- Understanding of the relationship between building's downtime and its surrounding environment/critical infrastructure.
- Better understanding of losses and monitor on a real-time basis including a vision-based approach with before and after shots to see if losses are evolving over time.
- Better understanding of the drivers of losses – how to "prevent hazards from becoming disasters".

Evaluation of Societal Impact by Wind Hazards



Societal impacts include loss of habitat for residents and relocation of offices and closing of businesses. These have major impacts on economic well-being of the society and suffering by people. Research in supply chain, labor market, and sociology can advance in understanding of impact and mitigating in future storms. Big data, social survey and statics are employed to pursue research.

- Business interruption - How to incentivize mitigation actions through public policies?
- Power infrastructure's impact on buildings and communities.
- Impact of climate change

Community Resilience

Community resiliency is gained by providing robustness of buildings and infrastructure and improving ability to recover quickly from damage caused by windstorms. Innovative new building products and approaches to retrofit building and infrastructure systems can improve resiliency. Analytical methods and experimental testing are pursued to develop products to enhance resiliency.

- Holistic approach for design of façade systems including the rating of different systems and the need to improve current standards. Research that will help achieve performance-based wind engineering.
- 'Smart Structures' – how individual components behave over time.
- Vibration of cladding as affected by building frequency can be examined beyond the current building codes.
- Science-based research to interpret the dynamic effect, water intrusion, and aging.
- How to transition from wind loading characterization to structural testing.
- Research on pre-engineered metal buildings.
- Development of a post-storm building assessment protocol.
- Develop method for identifying roof age and product.
- Evaluation of sheathing products' performance.
- Research on mobile or manufactured homes.
- Research on tree fall risk, based on tree species and soil condition.

TYPICAL EXAMPLES OF RESEARCH PROJECTS

- *Estimating surface wind conditions in landfalling hurricanes from dual-Doppler wind fields*
- *Prediction of wind and surge damage to buildings by hurricane*
- *Investigation of wind performance of roofing elements using full-scale experimentation*
- *Global compilation of best building practices in residential construction for withstanding wind hazards*

- *Investigation of wind-driven rain and wind-induced vibrations effects on curtain wall systems*
- *Estimation of interior and contents damage due to wind-driven rain ingress into mid/high rise buildings*
- *Assessment to Human Comfort during Wind-Induced Vibrations of Curtain Wall Systems*
- *Wind-induced loads on irregular shaped buildings*
- *Numerical simulation prediction on hail impact resistance performance of roof asphalt shingles*
- *Cost-effective and high-performance vision-based measurement system for real-time monitoring of structural dynamic responses*
- *Evaluation of Dynamic Wind Loads on Buildings by Wall-Modeled Large-Eddy Simulation*
- *Assessment of inelastic wind load effect of tall buildings for performance-based design*
- *Resiliency Enhancement of Electrical Distribution Networks against Wind-induced extreme weather events*
- *Probabilistic Projections of Sea-Level Rise for Infrastructure Resilience*
- *Development of Fragility Curves for Tornadic Loading on Low-Rise Buildings*