ADVANCES IN HURRICANE ENGINEERING

LEARNING FROM OUR PAST

PROCEEDINGS OF THE 2012 ATC & SEI CONFERENCE ON ADVANCES IN HURRICANE ENGINEERING

October 24-26, 2012 Miami, Florida

SPONSORED BY Applied Technology Council

The Structural Engineering Institute (SEI) of the American Society of Civil Engineers

EDITED BY Christopher P. Jones, P.E. Lawrence G. Griffis, P.E.







Published by the American Society of Civil Engineers

Acknowledgments

Hurricane engineering has evolved since Hurricane Andrew wreaked havoc on South Florida and Louisiana 20 years ago. One of the most devastating natural disasters in United States history, Andrew taught us much about how these powerful storms affect our built environment.

The Applied Technology Council (ATC) and the Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE) teamed up to present the Advances in Hurricane Engineering Conference – Learning from our Past, in Miami, October 24-26, 2012. This is the second joint conference of these two organizations in a growing partnership to benefit the engineering community and to make our communities more resilient to natural hazards.

This conference highlights what we've learned since Hurricane Andrew, and how these lessons have affected losses, and identifies what we still must learn to further improve hazard resistance.

When we gathered at this event, we will look at how we must continue to learn from our past so that we can improve the performance of our built environment to withstand the power of hurricanes.

Thank you to everyone who participated in making the Conference a tremendous success whether it was attending, presenting or helping to organize the event.

Christopher P. Jones & Associ

Christopher P. Jones & Associates Conference Co-Chairman

Larry Griffis, P.E., F.SEI., M.ASCE

Walter P. Moore & Associates, Inc.

Conference Co-Chairman

Conference Steering Committee

Ron Cook, Ph.D., P.E., M.ASCE University of Florida

Scott Douglass, Ph.D., P.E., D.CE, M.ASCE University of South Alabama

Peter Irwin, Ph.D., P.E., F.ASCE Rowan Williams Davies & Irwin, Inc.

Andrew Kennedy, Ph.D., M.ASCE University of Notre Dame

David O. Prevatt, Ph.D., P.E. University of Florida

Tim Reinhold, Ph.D., P.E., M.ASCE Insurance Institute for Business & Home Safety

Don Resio, Ph.D. University of North Florida

Spencer Rogers, M.ASCE North Carolina Sea Grant

T. Eric Stafford, P.E.

T. Eric Stafford & Associates, LLC

American Society of Civil Engineers 1801 Alexander Bell Drive Reston, Virginia, 20191-4400

www.pubs.asce.org

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document. ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefore. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing this information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers—Registered in U.S. Patent and Trademark Office.

Photocopies and permissions. Permission to photocopy or reproduce material from ASCE publications can be obtained by sending an e-mail to permissions@asce.org or by locating a title in ASCE's online database (http://cedb.asce.org) and using the "Permission to Reuse" link. *Bulk reprints*. Information regarding reprints of 100 or more copies is available at http://www.asce.org/reprints.

Copyright © 2013 by the American Society of Civil Engineers and the Applied Technology Council.

All Rights Reserved. ISBN 978-0-7844-1262-6 Manufactured in the United States of America.

Table of Contents

Building Code

ASCE 7: New Research

Considering the Directionality Factor in ASCE 7 Sylvia T. Laboy, Sonya Kalisz, Kurtis Gurley, and Forrest Masters	1
The Effects of Warm Atlantic Ocean Sea Surface Temperatures on the ASCE 7-10 Design Wind Speeds Peter J. Vickery and Francis M. Lavelle	13
Wind-Induced Force and Torque on a Sign Measured in Full Scale in the Field Douglas A. Smith, Delong Zuo, and Kishor C. Mehta	23
Building Codes and Floods: How Far We've Come	
Flood Damage-Resistant Materials: Research and Evaluation John Ingargiola and Julia Moline	34
Introduction to the FEMA Substantial Improvement/Substantial Damage Desk Reference and the FEMA Substantial Damage Estimator Gregory P. Wilson, Rebecca C. Quinn, and Don Glondys	48
ASCE 24: Improving the Performance of Buildings and Structures in Flood Hazard Areas John L. Ingargiola, Christopher P. Jones, and Rebecca C. Quinn	53
Flood Provisions in the International Code Series and 2010 Florida Building Code John L. Ingargiola and Rebecca C. Quinn	67
Critical Review of ASCE 7-10 Wind Loads	
Observations on ASCE 7-10 Methods for Determining Wind Loads Emil Simiu, Chris Letchford, Nicholas Isyumov, Arindam Gan Chowdhury, and DongHun Yeo	81
Hurricane Resistant Design for Coastal Residential Structures	
Foundation Design in Coastal Flood Zones William L. Coulbourne	92
Survival Analysis of Elevated Homes on the Bolivar Peninsula after Hurricane Ike Tori Tomiczek, Andrew Kennedy, and Spencer Rogers	108
FEMA's Coastal Construction Manual Update—Wind Resistant Design Andrew Herseth, Thomas L. Smith, and Glenn Overcash	119
FEMA's Coastal Construction Manual Update—Flood-Resistant Design Daniel Bass and Vasso Koumoudis	128
Wind vs. Water	
Wind versus Water: Determining the Cause of Coastal Building Damage in Hurricanes Scott L. Douglass and Caren R. Dixon	136

Distinguishing Damage Due to Wind versus Floods—An ASCE Publication David B. Peraza	145
Katrina on Trial—Forensic Hindcasting the Most Costly Storm David McGehee and Michael Griffin	152
Separating Junk Science from Sound Engineering Principles during Forensic Assessments of Hurricane Damage Michael Horst, Darren K. Howard, and Ralf Leistikow	165
Building Envelope	
A Systems Based Approach to Retrofitting Residential Structures to Reduce Hurr Damage	icane
Cost-Effectiveness of Wind Retrofit Measures Manuel Perotin	177
Retrofitting a Historic Building Envelope for Disaster Resilience and Sustainability Janice Olshesky	188
Evolution of Insurance Incentives for Wind-Resistant Construction since Hurricane Andrew J. C. Sciaudone and F. M. Lavelle	200
IBHS FORTIFIED Homes Hurricane: Bronze, Silver, and Gold; An Incremental Holistic Approach to Reducing Residential Property Losses in Hurricane Prone Areas Fred Malik, Remington Brown, and William York	212
FEMA's Wind Retrofit Guide Daniel L. Bass and Glenn Overcash	229
Quantification and Application of Dynamic Wind Pressure	
Wind Loads on Components of Multi-Layer Wall Systems with Air-Permeable Exterior Cladding Anne D. Cope, Jay H. Crandell, David Johnston, Vladimir Kochkin, Zhuzhao Liu, Larry Stevig, and Ti	238 mothy A.
Reinhold	
Evaluation of the Wind Pressure Performance of Walls with Exterior Rigid Foam Sheathing Vladimir Kochkin, Ryan Davies, and Andrew DeRenzis	258
Water Intrusion in Low Rise Buildings	
A Parametric Representation of Wind-Driven Rain in Experimental Setups Thomas Baheru, Arindam Gan Chowdhury, Girma Bitsuamlak, and Ali Tokay	270
Water Entry through Roof Sheathing Joints and Attic Vents: A Preliminary Study Stephen L. Quarles, Tanya M. Brown, Anne D. Cope, Carlos Lopez, and Forrest J. Masters	283
The Relationship between the Wind Damage Sustained by a Residential Building and Its Floor Area Charles Menun and Mohsen Rahnama	295
Wind Uplift Capacity of Foam-Retrofitted Roof Sheathing Subjected to Water Leaks	305

David O. Prevatt, Kenton McBride, David B. Roueche, and Forrest J. Masters

Building Envelope and Large Structures

F	Δ	n	Δ	C.	tı	ra	٠t	i	0	r	`	D	r	1	t	Δ	^	t	i۱	a	r	١
•	·		·	J		u		•	v	4	•	•	•	v	·	·	J	·		J	•	ı

Tellestration Folection	
Engineering Standards for Glazing Performance P. J. Condon	316
Residential Fenestration Vulnerability to Windborne Debris Sylvia Laboy, Daniel Smith, George Fernandez, Forrest Masters, and Kurtis Gurley	328
Design and Field Testing of Windows/Doors in Hurricane Zones Jeffrey M. Hugney	337
Protection and Performance before, during, and after the Storm Julia Schimmelpenningh	349
Glass Curtain Walls in High Rise Structures	
Superior Structural Silicone Glazing Charles D. Clift, Lawrence D. Carbary, Peter Hutley, and Jon Kimberlain	357
Hazard Mitigation of the Building Envelope: Are Our Building Envelopes Ready for a Powerful Storm? Rick De La Guardia	381
Forensic Studies of Surface-Damaged Curtain Wall Glass M. K. Schmidt and R. A. Cechner	393
Anatomy of Glass Damage in Urban Areas during Hurricanes K. Butler and A. Kareem	405
Hurricane Wind Loads on High Rise Buildings	
Structural Wind Engineering of High-Rise Towers in Hurricane-Prone Regions Jason Garber, Gary Stone, and Peter Irwin	417
Wind Engineering of the Shanghai Center Tower Derek Kelly, Dennis Poon, Peter Irwin, and Jiming Xie	426
An Examination of Wind-Related Design Criteria and Their Applications in Hurricane Regions R. O. Denoon and W. S. Esterday	437
Building Roofs	
Environmental Loading of Solar Collectors	
Wind Turbulence and Load Sharing Effects on Ballasted Roof-Top Solar Arrays	448

В

Ε

Wind Turbulence and Load Sharing Effects on Ballasted Roof-Top Solar Arrays Matthew Browne, Scott Gamble, and Michael Gibbons	448
Wind Loads on Low Profile Tilted Solar Arrays Placed on Low-Rise Building Roofs Gregory A. Kopp	460
Full Scale and Wind Tunnel Testing of a Photovoltaic Panel Mounted on Residential Roofs	471

James Erwin, Girma Bitsuamlak, Arindam Gan Chowdhury, Stephen Barkaszi, and Scott Gamble

Roof Coverings

Life-Cycle Assessment of Personal Residential Roof Decking and Cover under Hurricane Threats	483
JP. Pinelli, T. Johnson, G. L. Pita, and K. Gurley	
Wind Tunnel Model Studies of Aerodynamic Lifting of Roof Pavers Peter Irwin, Calin Dragoiescu, Michael Cicci, and Greg Thompson	496
Wind Load on Ridge and Field Tiles on a Residential Building: A Full Scale Study Amanuel Tecle, Girma T. Bitsuamlak, and Arindam Gan Chowdury	506
Investigation of the Wind Resistance of Asphalt Shingles C. R. Dixon, F. J. Masters, D. O. Prevatt, and K. R. Gurley	517
Roof Top Equipment	
Solar Panel Installations on Existing Structures Tim Sass, Sara Sass, and Kim Sass	528
Roof Curb Design: For Compliance with Building Code Seismic and Wind Load Requirements P. J. Selman	539
Design of RTU Curbs for Hurricane Winds R. F. Oleck and D. W. Herrit	544
Full Scale and Wind Tunnel Testing of Rooftop Equipment on a Flat Roof James Erwin, Arindam Gan Chowdhury, and Girma Bitsuamlak	553
Flooding	
Climate Change and Sea Level Rise	
Damage Simulation System for Coupled Hazards Caused by Maximum Possible Typhoons in Coastal Zones under a Future Climate T. Murakami, J. Iida, J. Yoshino, and T. Yasuda	561
Influence of Climate Change on Future Hurricane Wind Hazards along the US Eastern Coast and the Gulf of Mexico Fangqian Liu and Weichiang Pang	573
Coastal Flood Risk Evaluation	
Rapid Probabilistic Assessment of Wave and Surge Hurricane Risk Alexandros A. Taflanidis, Andrew B. Kennedy, Joannes J. Westerink, and Jane Smith	585
Rapid Estimation of Storm Surge within the Disaster Response Intelligent System (DRIS) H. Das, HS. Jung, G. Skelton, and R. Whalin	597
Advanced Estimation of Coastal Storm Surge: Application of SWAN+ADCIRC in Georgia/Northeast Florida Storm Surge Study A. Naimaster, C. Bender, and W. Miller	607

Cyber-Eye: Integrated Cyber-Infrastructure to Support Hurricane Risk Assessment T. L. Kijewski-Correa, A. A. Taflanidis, A. B. Kennedy, A. Kareem, and J. J. Westerink	618
Hurricane Observation and Flood Damage	
FEMA Mitigation Assessment Team Program: Observations and Recommendations since Hurricane Andrew Andrew Herseth and Erin Ashley	630
Hurricane Irene: Damage Observations along the Eastern Seaboard P. Datin, C. Cabrera, and R. Vojjala	646
Post-Andrew Improvements in Hurricane Storm Surge and Wave Observations	
A Wave, Water Level, and Structural Monitoring Plan for Dauphin Island, Alabama B. M. Webb, A. Kennedy, S. Rogers, U. Gravois, and H. Omar	658
The Evolution and Development of Improved Data Collection Methods and Mobile Networks for the Observation of Inland Hurricane Storm Surge Robert R. Mason, Jr., Paul A. Conrads, Jeanne Robbins, Brian E. McCallum, and Charles Berenbrock	666
Storm Surge and Wave Effects on Bridges	
A Simplified Reliability-Based Method in Estimating Losses to Fixed Offshore Oil Platforms in GOM P. Apirakvorapinit and S. Daneshvaran	679
Fragility Assessment of Coastal Bridges under Hurricane Events Using Enhanced Probabilistic Capacity Models Navid Ataei and Jamie E. Padgett	691
Storm Surge Risk Return Periods	
Joint Distributions of Hurricane Wind and Storm Surge for the City of Charleston in South Carolina	703
Bin Pei, Weichiang Pang, Firat Testik, and Nadarajah Ravichandran	
Storm Surge Return Periods for the United States Gulf Coast Hal F. Needham, B. D. Keim, D. Sathiaraj, and M. Shafer	715
Wave and Rainfall Contributions to Coastal Flooding	
The Role of Tropical Cyclone Induced Flooding in Economic and Insurance Losses C. Kafali and V. Jain	741
Wave Effects on Hurricane Storm Surge Simulation L. T. Phan, D. N. Slinn, and S. W. Kline	753
An Engineering Approach for Modeling Hurricane Extreme Waves Using Analytical and Numerical Tools Gabriel Diaz-Hernandez Lucia Robles Christian M. Appendini, Fernando J. Mendez, Alec Torres-Frey	765

Infrastructure

Inigo J. Losada, and Paulo Salles

Advanced Technology for Storm Data Collection

High Resolution Imagery Collection Utilizing Unmanned Aerial Vehicles (UAVs) for Post- Disaster Studies Stuart M. Adams, Marc L. Levitan, and Carol J. Friedland	777
The Fundamentals of Modernizing Damage Assessment Tools Adam Reeder	794
Recent Advances towards a Robust, Automated Hurricane Damage Assessment from High-Resolution Images Jim Thomas, Ahsan Kareem, and Kevin Bowyer	806
Critical Facilities	
Challenges Encountered Retrofitting an Existing Concrete Building Classified As an Essential Facility Regan Milam and James Snow	816
ICC 500-2008: ICC/NSSA Standard for the Design and Construction of Storm Shelters Kimberly Paarlberg and Dave Bowman	826
Introduction to FEMA's Guidance Document: Emergency Power for Critical Facilities Gregory Wilson and David K. Low	837
Wind Effects on Power Systems	
Failure Risk of 230 kV Electricity Transmission Lines in South Carolina under Hurricane Wind Hazards Weichiang Pang, Zhiqiang Chen, Fangqian Liu, and Ryan Holmes	840
Fragility Assessment of Wood Poles in Power Distribution Networks against Extreme Wind Hazards Abdollah Shafieezadeh, Precious U. Onyewuchi, Miroslav M. Begovic, and Reginald DesRoches	851
Large Structures	
Florida Marlins Retractable Roof Ball Park: Design and Construction	
The Hurricane Roof Position Jonathan B. Lankin, Peter A. Irwin, Gary K. Stone, Jason Garber, and Matthew T. Browne	862
Meteorology	
Assessment and Mitigation of Multi-Hazard Effects in Hurricanes	
Cyclone Risk from Wind, Flood, and Storm Surge Perils in Australia: A Comprehensive Model	877
K. Butler, C. Kafali, and V. Jain	
Hurricane Evacuation Decision Support Framework—A Risk Based Approach Jason P. Fennell and Samuel D. Amoroso	889
Robustness versus Resilience: Hurricanes and Other Natural Hazard Risks Ross B. Corotis	900
Hurricane-Related Infrastructure Damage	912

D. A. Reed and A. Gonzalez

Hurricane Meteorology

name more energy	
The Effect of Averaging Duration on Differences Observed between Gust Factors from Tropical and Extratropical Winds Rebecca Paulsen Edwards and John L. Schroeder	918
Wind Profile and Spectra in Typhoon-Prone Regions in South China Lixiao Li, Ahsan Kareem, Yiqing Xiao, Lili Song, and Peng Qin	929
Tropical Cyclone Marine Surface Wind Modeling: The Shape of the Radial Wind Profile Matters	941
Vincent J. Cardone and Andrew T. Cox	
Probabilistic Modeling of Local Wind Pressure	
Estimation of Peak Wind Pressure on a Low-Rise Building Luping Yang, Xinlai Peng, Eri Gavanski, Kurtis Gurley, and David Prevatt	960
Framework for the Assessment of Building Envelope Failures Due to Hurricane Wind Hazards	970
J. Michael Grayson, WeiChiang Pang, and Scott Schiff	
Probabilistic Estimation of Extreme Wind Loads on Low-Rise Structures S. Ben Ayed, M. R. Hajj, S. A. Ragab, and H. W. Tieleman	982
Posters	
Finite Element Evaluation of Modal Stresses in Cantilever Highway Sign Structures Masood Hajali and Caesar Abishdid	994
Development of Computational Tools for Large Scale Wind Simulations Daniel Abdi and Girma T. Bitsuamlak	1006
In Situ Nail Withdrawal Strengths in Wood Residential Roofs Sushmit Shreyans, Ashlie Kerr, David O. Prevatt, and Kurtis R. Gurley	1017
Probabilistic Approach to Determining Internal Pressures Based on Wind Tunnel Measurements	1027
Jan Dale, Peter Irwin, Suresh Kumar, John Kilpatrick, and Jon Galsworthy	
Finite Element Modeling of the Progressive Failure of a Low-Rise Building under Uniform Uplift Pressure F. Pan and C. S. Cai	1035
Risk Modeling	
Hurricane Risk Modeling: Latest Developments and Opportunities	
Analysis of Hurricane Andrew Insurance Claim Data for Residential Buildings Gonzalo Pita, Jean-Paul Pinelli, Judith Mitrani-Reiser, Steve Cocke, and Kurt Gurley	1047
Constructing and Validating Geographically Refined HAZUS-MH4 Hurricane Wind Risk Models: A Machine Learning Approach	1056

D. Subramanian, J. Salazar, L. Duenas-Osorio, and R. Stein	
Interactions among Wind Mitigation Features in Benefit/Cost Analysis Francis M. Lavelle and Peter J. Vickery	1067
Wind Loading	
Full Scale Wind Testing	
Analysis of Wood-Framed Roof Failures under Realistic Hurricane Wind Loads Gregory A. Kopp, Mohammad Abrar Alam Khan, David J. Henderson, and Murray J. Morrison	1078
A New Simulator to Recreate Extreme Dynamic Loads on Large-Scale Building Component and Cladding Systems S. Y. Shen, F. J. Masters, and H. Upjohn II	1090
Evaluation of Wind-Induced Structural Attenuation Based on Full-Scale Monitoring I. Zisis and T. Stathopoulos	1098
Comparison of Field and Full-Scale Laboratory Peak Pressures at the IBHS Research Center	1109
Murray J. Morrison, Tanya M. Brown, and Zhuzhao Liu	
Parapet Effects on Full-Scale Wind-Induced Roof Pressures Russell R. Carter and Douglas A. Smith	1125
Hurricane Damage Mitigation in the Caribbean and Latin America	
Design Wind Speeds in the Caribbean Peter J. Vickery	1136
An Overview of the Caribbean Coastal Ocean Observing System and Data Measurements during Hurricane Irene	1148
Luis D. Aponte, Miguel F. Canals, Jorge E. Corredor, and Julio M. Morell	
A Holistic Approach to Ensuring That Hospitals Function at Maximum Efficiency Following Severe Hurricanes in the Caribbean Tony Gibbs	1160
Panel Session: NIST Advances in Computer-Aided and Computational Methods in Engineering	า Wind
NIST Advances in Computer-Aided and Computational Methods in Wind Engineering D. Yeo, F. Lombardo, D. Banerjee, E. Letvin, F. A. Potra, E. Simiu, and M. Levitan	1171
Performance-Based Wind Engineering	
Probabilistic Performance Based Risk Assessment Considering the Interaction of Wind and Windborne Debris Hazards	1183
Vipin U. Unnikrishnan, Michele Barbato, Francesco Petrini, and Marcello Ciampoli	
Extreme Wind Risk Assessment of the Miami Marlins' New Ballpark in Miami, Florida Nathan C. Gould, Rolando E. Vega, and Stephanie H. Sheppard	1194
A Framework for Performance-Based Wind Engineering Lawrence Griffis, Viral Patel, Susendar Muthukumar, and Sridhar Baldava	1205

Performance-Based Evaluation of an Existing Building Subjected to Wind Forces

1217

Susendar Muthukumar, Sridhar Baldava, and Jason Garber