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August 25, 2006

Ms. Iris Stanley
Division of Housing and Community Development
Florida Department of Community Affairs
2555 Shumard Oak Boulevard
Tallahassee, FL 32399-2100

RE: FINAL REPORT
Contract # 06RC-A%-13-00-05-261

Dear Ms. Stanley:

In compliance with contract of the reference, I am pleased to herewith enclose our final report for the research project ***Hurricane Loss Reduction for Housing in Florida*** conducted by the International Hurricane Research Center (IHRC) at Florida International University (FIU). This report summarizes our research activities from July 1, 2005 through July 31, 2006. This report complies with the required reporting requirements per the contract agreement.

The IHRC team looks forward to continuing to work with you and to be of service to the residents of our state. Please contact me if you have a questions or comments.

Sincerely,

Stephen Leatherman
Director

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A Resource for the State of Florida

HURRICANE LOSS REDUCTION FOR HOUSING IN FLORIDA

FINAL REPORT
For the Period July 1, 2005 to July 31, 2006

A Research Project Funded by
The State of Florida Department of Community Affairs
Through Contract # 06RC-A%-13-00-05-261

PREPARED BY
THE INTERNATIONAL HURRICANE RESEARCH CENTER
FLORIDA INTERNATIONAL UNIVERSITY

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Executive Summary

Hurricanes are among the most destructive and costliest of all natural disasters, and since 1995 the United States entered a cycle of more intense hurricane activity. Florida has been hit by eight hurricanes in the past two years, resulting in 2.9 million claims and $31.3 billion in insured losses. The possibility of a major hurricane striking a large population center in Florida during the next 20 to 30 years of high activity emerges as a near certainty. Regardless, the US will continue to lose an average of $4 billion to tropical cyclone impacts and an additional $1.3 billion to other extreme wind events. As populations continue to increase in Florida coastal regions where the threat is highest, so does the possibility for even greater destruction. This risk can be devastating for entire communities, for the insurance industry, which ultimately must pay for a significant portion of the incurred losses, for local and state government who have to struggle with the impact on their populations and economies, and for the nation as a whole. For these reasons it is essential to reduce the destruction expected from future events.

Structural mitigation can result in significant hurricane loss reduction. The Residential Construction Mitigation Program is making a critical contribution to the State of Florida by ensuring that the built environment will have a better chance of surviving future impacts from hurricanes. Continued RCMP funding has allowed the development of an innovative research capability in full-scale structural testing to determine inherent weakness of structures when subjected to hurricane-force winds and rain. The Wall of Wind testing apparatus will permit a fundamental understanding of the failure mode of buildings and hence lead to technologies and products to mitigate hurricane impacts.

This executive summary highlights findings discovered through the dedication of over 20 researchers and students from four universities. Periodic communication via e-mail and telephone conferences has also contributed to keeping our effort on target and within established timelines. The below sections summarize stated objectives for the 2005-2006 research period.

Annual Report to the Florida Legislature

The IHRC assisted DCA in the preparation of a full annual report and accounting of activities under section 215.559, Florida Statutes, Residential Construction Mitigation Program. The report was submitted by DCA to the Speaker of the House of Representatives, President of the Senate, and the Majority and Minority Leaders of the House of Representatives and Senate on January 1, 2006.

Full Scale Simulation of Wind, Water and Structural Interaction

A Preliminary Investigation of Wind-Driven Rain Intrusion Through Soffits

Damage reconnaissance studies conducted after the 2004 and 2005 hurricanes found that many single-family low-rise homes remain vulnerable to wind-driven water intrusion through soffits. While many homes survived structurally, they experienced enough rain penetration to require interior restoration and in some cases, occupant displacement until the completion of repairs. This preliminary study investigates wind and wind-driven rain resistance design requirements for soffit performance in a design-level hurricane event using full-scale testing techniques. Findings will lead to developing design solutions for new homes and retrofitting techniques for existing homes using the most efficient combination of bracing, anchorage, blocking and modified panel shapes from common construction materials. To simulate wind-driven rain intrusion through a soffit, the Phase I Wall of Wind testing apparatus was utilized to create a wind and wind-driven rain field sufficiently large enough to envelop a partial mockup of a house wall/roof system.

The wind generator—known as the Phase I Wall of Wind—is a portable two-engine array fabricated by Diamondback Airboats in the spring of 2005. The Wall of Wind was developed by Florida International University; funding was provided by the Florida Department of Community Affairs through the Residential Construction Mitigation 2004-2005 Program. Vertically stacked PCM 496 in^3 motors drive counter-rotating planetary drive units, which turn two 70+ in airboat carbon fiber propellers. At the exit, a water injection system creates wind-driven rain which travels through 12 ft wall enclosures before impinging on the test

subject. During this performance period major modifications were carried out to improve testing capabilities. These modifications include:

- Replacement of the mufflers with silencers which decreased the sound intensity
- Replacement of the manual cable system with digital, titanium-gear, coreless, ball-bearing servos to actuate the throttle body.
- Addition of a hydraulic pump, a solenoid-operated proportional flow control valve, a custom hydraulic cylinder and a rotary potentiometer to measure angular displacement to move the rudder system quickly and accurately
- The addition of water injection system

FIU researchers completed four major rounds of soffit testing during January 2-6, March 16-17, May 22-23 and July 26-28, 2006. The soffit testing rig included a roof and wall assembly that could be quickly and easily adjusted to create overhangs of various lengths. Smoke, fluorescent tracer dye and high speed camera imagery were used to aid in experimentation visualization. A total of six soffit systems were tested including: hidden vent soffits, perforated vinyl soffit, perforated aluminum soffit. The fourth and fifth soffits were hybrid perforated systems and the sixth specimen was custom fabricated. Some key findings showed:

- The perforated vinyl soffit outperformed the hidden vent and the perforated aluminum soffits
- The perforated aluminum soffit outperformed the hidden vent soffit
- Considerable pooling of water was observed on the top of the hidden vent soffit panels.
- Modifying the hidden vent system with deflectors reduced the rate of intrusion by 69-79% compared to the unmodified system.
- The material flaps on the back of the catch basin for the perforated aluminum soffit had a dramatic effect. Collection rates increased by approximately 360% in the lower two wind regimes and 600% at 115 mph
- The baffle system as installed was the worst performer, but the investigation was only limited to one configuration

Wall of Wind: Assistance in Development of Phase I and Testing of Soffits for Water Penetration

University of Florida researchers provided storage and assistance for the FIU researchers to conduct soffit testing. Activities included the construction of soffit testing apparatus, assisting with upgrades to the water injection system, mechanical maintenance and modification of the WOW engines and in the performance of soffit testing.

Adapting Wireless Technology for the Wall of Wind: A Pilot Study

The implementation of affordable solutions to mitigate damage can only follow from a quantification of the wind forces causing this destruction. An accurate description of fluctuating wind loads is the key to defining the ability of structural components to resist damage, and thus evaluate retrofits. True wind load characterization requires comprehensive full-scale measurements which are difficult to obtain given the random nature of hurricane occurrence. The Wall of Wind, currently being developed at FIU, offers a solution to this problem, since it will allow the mimicking of hurricane wind conditions on full-scale structures and components. The focus of this project was the development of wireless instrumentation to complement the ongoing Wall of Wind tests. A group of researchers at Florida Tech adapted a new wireless sensing system to allow affordable, rapid, reliable, and secure deployment of sensors on a variety of structures or sub-structures to be tested in the Wall of Wind. These tests will complement similar full-scale tests carrying on during hurricane and other extreme wind events, on full-scale coastal structures in Florida.

Performance of Tile Roofs Under Hurricane Impact

In the last two years, the State of Florida has been impacted by an unprecedented number of hurricanes. While many would remember the devastating impact of Hurricane Katrina in New Orleans, its damage in South Florida was not insignificant. Similarly, Hurricane Wilma damaged many houses in Miami-Dade and Broward counties to the extent that they are still recovering with blue tarps still in use. Particularly for a Category 1 hurricane, Wilma has challenged the building codes in South Florida as they relate to roof covering. While most homes suffered little structural damage, many experienced roof covering failures, and especially lost a large number of tiles on the ridgelines.

The critical issues at hand are; (a) whether there is a significant difference in performance of clay tiles and concrete tiles and, if so, why, (b) whether the current building codes provide adequate and reasonable measures for proper performance of tile roofs, and (c) what, if any, change is necessary to improve the way tile roofs are installed.

A detailed experimental and analytical study was carried out for ridge clay and concrete tiles with adhesive-set, mortar-set, as well as mechanical attachments. The strongest system appeared to be concrete tiles with mortar. While concrete tiles bond to mortar much better than clay tiles, clay tiles adhere better to the foam. Concrete tiles also perform better than clay tiles when mechanical fasteners are used with an embedment length of at least 1 inch. Therefore, the present study does not support recent efforts by the industry to completely ban the use of mortar for all attachments of hip and ridge tiles. However, it is suggested that any such ban on mortar be limited to clay tiles only.

Tropical Cyclone Conditions in Typical Florida Neighborhoods

Comparing Full-Scale and Wind Tunnel Results

The primary goal of this project is analysis of field data of wind pressures and wind tunnel studies on models of houses located in a typical Florida neighborhood. The research was conducted by Clemson University in partnership with Florida International University and University of Florida.

Five instrumented prototype homes were hit by tropical cyclone-strength winds during 2004, yielding pressure and wind speed data for further analysis. The field data included near-ground level hurricane-strength wind speeds and directions, and pressure measurements from sensors located in critical corner roof areas of houses situated in residential neighborhoods. Researchers conduct field investigations at the houses to record location of surrounding buildings, and large obstructions relative to the prototype house. The team then analyzed pressure server data and available wind speed data to derive pressure coefficient time-histories for the houses affected by the hurricanes.

ASCE 7 wind design pressure coefficients are based on research conducted in boundary layer wind tunnels. There is limited full-scale data available to validate wind load results. Wind tunnel studies on models of the prototype houses need to be compared to full-scale results with wind tunnel studies. Researchers conducted wind tunnel studies to develop a pressure coefficient database to serve as a baseline for future studies that include the wind load variation in open and suburban terrain. Wind tunnel results were then compared to incident wind with prototype pressure data derived from the houses in the storm direction.

Quantifying Effects of Pruning on Tree Responses from Wind Loading

Effects of Pruning on Trunk Movement in Wind

This study was conducted at the University of Florida in coordination with the International Hurricane Research Center (IHRC) at Florida International University. The goal was to determine how different pruning techniques effect trunk movement on 20 ft. live oaks. The three pruning treatments studied were thinning, reducing, and raising of the canopies. The trees were blown by the Wall of Wind testing apparatus with a maximum wind speed up to 120 mph, maintained for three minutes. The trees that were tested were *Quercus virginiana* 'Cathedral' cultivar. This species was selected because it is a commonly used tree in urban landscapes and because the trees were clones that were propagated from cuttings. Each tree was instrumented with three orientation sensors at set heights along the trunk to measure its deflection in all three axes.

A significant difference in trunk movement between the control and the three pruning treatments was observed. This implies that pruning trees reduces trunk movement, and thus reduces the risk of tree failure under high wind speeds. Trunk movement was minimized with the thinning and reducing treatments. More research is warranted in this area of research, including the testing of different species, different pruning doses, and testing the effect of wind speeds for different durations.

Age Based Wind Retrofit Selection for Existing Public Facilities

Wind Provision Evaluation from the 2005 Florida Building Code for Hurricane Vulnerability Mitigation

The Florida Building Code 2001 (FBC-01) was implemented statewide, beginning July 1, 2002. Overall, the new building code is more stringent than the past codes such as the Standard Building Code (SBC) and the South Florida Building Code (SFBC), to mitigate past hurricane related design/construction problems. However, the actual effect of the enhanced wind provisions on the design and the cost of typical Florida coastal buildings are not known. The wind provisions of FBC-01 are based on the ASCE 7-98 provisions, with some modifications. The next version of the FBC (FBC-05) was implemented in 2005 statewide. The new version is based on the International Building Code (IBC), where the wind provisions are based on ASCE 7-02. However, FBC-05 wind provisions are based on the earlier ASCE 7-98 provisions. In general, the ASCE 7 provisions are based on past wind tunnel data. They have not been calibrated for recent hurricane damage. There also exists confusion regarding the Main Wind Force Resisting System (MWFRS) and Components and Cladding (C&C) wind pressure applicability. The IBC provisions for the first time will enforce separate wind provisions for residential and commercial facilities in Florida. The effect of this change on the end results is unknown. A comprehensive study to examine the various wind concerns, in respect to the changing building code situation in the state, is essential for proper hurricane preparedness and vulnerability mitigation. The goal of this project is to examine, analyze and clarify various wind design provisions from Florida Building Code (FBC) 2005.

State-wide and Focused Surveys to Assess Effectiveness of RCMP Programs

Single-Family Home Hurricane Mitigation Survey

The Metropolitan Center at Florida International University, in collaboration with the International Hurricane Research Center, conducted a statewide survey of Florida residents and single-family homeowners to determine their level of hurricane preparedness, perception of threat and attitudes towards different mitigation strategies. The survey results have serious

policy implications because they demonstrate predominant attitudes among Floridians regarding hurricanes which can be used to predict and model behavior.

The survey results demonstrate that Floridians have yet to embrace a culture of preparedness:

- Only 20% of Floridians discuss hurricane safety more than once every couple of months;
- Less than half (46.8%) of all Floridians will begin preparing their homes when a "Hurricane Warning" is issued; and
- Only 20.5% of Floridians would evacuate after a "Hurricane Warning" is issued.

However, Florida residents are becoming increasingly aware of the dangers of hurricanes:

- 46.1% of respondents feel extremely or somewhat vulnerable to hurricanes;
- 87.1% feel somewhat to very certain that they have all the information needed to protect themselves and their property from hurricane damage; and
- 85% have a plan if threatened by a serious hurricane.

While most Floridians believe the community would be better off if everyone protected their homes against hurricanes (86.8%) and would be in favor of their community undertaking a program to strengthen public buildings, utility lines and other infrastructure against hurricane damage (85.7%), Floridians seem to lag behind in their preparations.

- 48.6% of homeowners do not have any type of shutters or window coverings.
- 24.9% of those who reported they have some type of window coverings do not have shutters on all their windows.
- Of those who do not have shutters, 36.4% said they do not need, 30.6% said they could not afford them.
- Only 31.7% of residents whose home is located in an evacuation zone would evacuate if a major hurricane is predicted to hit their area within 24 hours.

In addition, Floridians do not seem willing to take any additional measures to protect themselves and their property from hurricanes by utilizing different programs for hurricane mitigation.

- Only half the respondents would be interested in a no-cost inspection program to inspect their homes and offer suggestions to make them more hurricane resistant.
- Other economic incentive program received less support:
  - 0% interest loan
  - A grant program offering up to $10,000
  - Lower annual insurance premiums

Programs of Education and Outreach to Convey the Benefits of Various Hurricane Loss Mitigation Devices and Techniques

The education and outreach components initiated this year built on the foundation of research and work predominately conducted during previous grant periods. Efforts this year were made to increase the level of awareness among the general public regarding the need for decreasing the vulnerability of building structures to hurricane-force winds. Partnerships were made with local and statewide organizations to coordinate interrelated activities and ensure cooperation among parties implementing hurricane loss reduction activities. Memoranda of Understanding were established with the Federal Alliance for Safe Home (FLASH) and the Disaster Survival House (DiSH). In addition the team continues to maintain a web page for the Laboratory for Wind Engineering Research under the URL: ***http://www.ihrc.fiu.edu/lwer/***.

Outreach was conducted at two statewide conferences to ensure that businesses, organizations, and agencies were aware of on-going research activities conducted through the RCMP program and the applications of this research to personal mitigation strategies. The conferences included the National Hurricane Conference in April 2006 and the Governor's Hurricane Conference in May 2006. Participation in these programs was by way of chairing workshops and delivering presentations focusing on hurricane loss mitigation. An exhibit booth complemented these presentations with IHRC staff present to answer questions and distribute information about research initiatives related to the topic of hurricane loss mitigation.

Researchers from the IHRC had continuous interaction and participation in the activities of the Miami-Dade County Local Mitigation Strategy (LMS) Working Group. IHRC representatives made several presentations throughout the year on issues related to hurricane loss mitigation, in general, and to the RCMP, in particular. On June 14, 2006 the IHRC hosted the LMS meeting at Florida International University. Approximately 100 participants including community leaders, researchers, policy makers, and blue-collar workers discussed the mitigation strategies implemented in Miami-Dade County.

The Disaster Survival House (DiSH), formerly the State Farm Good Neighbor House®, is a residential home located in Deerfield Beach, Florida built to withstand major hurricane force winds. The learning center was designated a Fortified Home by the Institute of Business and Home Safety during FEMA's Project Impact program. Hurricane and disaster education, safety and preparedness are taught to children, families, seniors, students and businesses. DiSH features a hurricane laboratory with a weather forecast center, examples of shutter protection and wind tunnel demonstrations. Hurricane forecasting, tracking, flooding, storm surge, lightning, surge protection, generator safety, safe room and preparedness planning are covered in a new educational tour. In addition, the National Safety Council, through their Home and Community program, teaches general family safety in the home.

The Disaster Survival House is owned by the City of Deerfield Beach and in partnership with the National Safety Council, Florida Atlantic University, Florida International University, International Hurricane Research Center and the American Red Cross. Under the RCMP program, IHRC purchased kiosk and printer systems to be located at the Disaster Survival House. The equipment is an integral component of the learning center's kiosk network used to disseminate mitigation information to the public. As part of our education and outreach effort under the RCMP program, the IHRC provides research findings/animations to the learning center. The kiosk stations located in individual showrooms provide a perfect platform to display these findings to Florida homeowners and children.

IHRC Project Research Team

The 2005-2006 research team was comprised as follows:

Principal Investigator:	Stephen Leatherman	FIU/IHRC
Project Manager:	Carolyn Robertson	FIU/IHRC

Principal Researchers:

Ed Gilman	UF	Agriculture
Kurt Gurley	UF	Civil Engineering
Forrest Masters	FIU	Wind Engineering
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Dario Moreno	FIU	Political Science
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