HURRICANE LOSS REDUCTION FOR HOUSING IN FLORIDA

A Research Project of the
International Hurricane Research Center
At Florida International University
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Under Contract 04-RC-11-13-00-05-001

FINAL REPORT

For the period July 1, 2003 to June 30, 2004

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PREPARED BY
THE INTERNATIONAL HURRICANE RESEARCH CENTER
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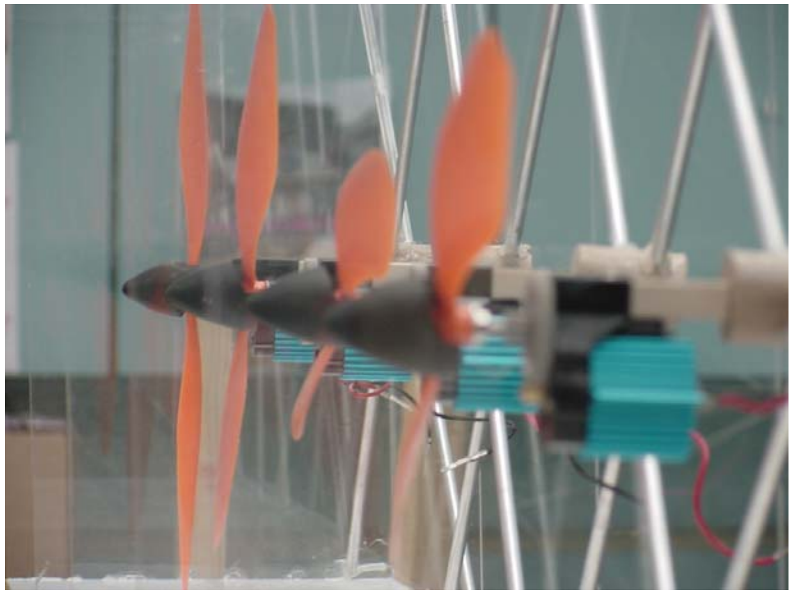
Volume 3
Chapter 3



Research and Development on Hurricane Loss Reduction Devices and Techniques for Site-Built Housing

Scope of Work:

Typically the HLMP grant period runs from July 1 through June 30, however for this research year the grant agreement between FIU and DCA was executed on November 12, 2003. Given the intervening Thanksgiving and other holidays in December, only modest progress was realized in 2003. Team organization, budgets and definition of scopes of work for the various members of the IHRC Team were the main achievements during 2003. In essence actual research only got underway in January of 2004. This means a little less than six months were really available for a twelve-month research agenda. This caused problems with respect to specific areas of research that were sensitive to the element of time.

In spite of this initial delay and the shortened time period to carryout the proposed research agenda considerable progress was made during the period from January 2, through June 30, 2004.

Under the *Budget and Scope of Work* submitted by the IHRC team Task #1**-** Areas of Research for the Period July 1, 2003 through June 30, 2004 - covers the three research tracks mandated by the State Legislature and reflected in the language of the *Bill Williams Residential Safety and Preparedness Act* [Florida Statutes section 215.559].

One of these research tracks focuses on *Hurricane Loss Reduction Devices and Techniques.* Work under this specific track looks at such truly fundamental questions as:

(a) How vulnerable are our communities to the impact of hurricanes?

(b) What are the damage components, within a hurricane, that are the main cause of direct damage to the built environment?

(c) What are some of the alternatives for reducing the potential for damage to housing the next time a hurricane impacts a given community if Florida?

(d) How effective are any of the mitigation measures in reducing such potential for damage, and how can we measure this effectiveness?

For work to be conducted under this track during the 2003-2004 research period the IHRC Team identified a range of possible specific research topics as listed below:

3.1 The Role of Impact Modifiers in Neighborhood Design.

3.2 Performance Modifiers in the Mitigation of Roof Damage.

3.3 Developing New Testing Protocols for Impact Testing.

3.4 Using Field Instrumentation to Assess Hurricane Impact on Housing.

3.5 Study of Roof to Wall Connections.

3.6 Focused Survey to Assess Effectiveness of HLMP Program.

3.7 Feasibility of Implementing Programs of Incentives to Include Hurricane Loss Mitigation Devices and techniques in the Design/Construction of New Housing or in the retrofit of Existing Houses.

3.8 Programs of Education and Outreach to Convey the Benefits of Various Hurricane Loss Mitigation devices and Techniques.

Research Titles and Players:

3.1.a **Role of Impact Modifiers in Neighborhood Design (pages 8-55)**

School of Architecture, Florida International University

Jason Chandler
Carlos Escuti
Michael Figueredo
Robert Perez
George Torrente

Department of Civil Engineering, Clemson University

Timothy Reinhold
Scott Robinett

3.1.b **Role of Vegetation as an Impact Modifier (pages 56-75)**

University of South Florida, School of Architecture and Community Design

Stephen Schreiber
Kevin Nickorick

3.2 **Performance Modifiers in Mitigation of Roof Damage (pages 76-89)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez

3.2.a **Research and Development for a Wall of Wind Study (pages 90-93)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez
Carolyn Robertson
Scott Caput
Sarah Goodridge
Brie Losego
Victor Camps

Department of Civil Engineering, Clemson University

Timothy Reinhold

3.2.b **Continued Testing of Roof-sheathing Fasteners (pages 94-106)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez
Carolyn Robertson
Brian Saponaro
Victor Campos
Brie Losego
Scott Caput

3.2.c **Comparative Cost-analysis for Various Roof-sheathing Fasteners (pages 107-108)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez

3.2.d **Research and Development of Modified-design for Drip-edge Roof Flashing (page 109)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez

3.2.e **Research and Development into the Effectiveness of Roof-edge Spoilers (page 110)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez

3.2.f **Assess the Performance of Various Types of Roof Coverings (pages 111-117)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez
Carolyn Robertson
Scott Caput
Brie Losego
Victor Camps

Center for Electronic Communication, Florida Atlantic University

Edmund Skellings
Francis McAfee
Diane Newman
Vivek Patel
Hsin Ju Yang

3.2.g **Research of Performance Improvement of Existing Roofs Built Prior to the Current Applicable Building Code through Various Retrofit Measures (pages 118-121)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez
Carolyn Robertson
Scott Caput
Brie Losego
Victor Camps
Brian Saponaro

3.2.h **Benefit-cost Analysis for Various Performance Modifiers (page 122)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez

3.3 **Developing New Protocol for Impact Testing (page 123)**

International Hurricane Research Center, Florida International University

Ricardo Alvarez
Carolyn Robertson
Scott Caput
Brie Losego
Victor Camps
Brian Saponaro

Center for Electronic Communication, Florida Atlantic University

Edmund Skellings
Francis McAfee
Diane Newman
Vivek Patel
Hsin Ju Yang

3.4 Improvement of Atmospheric Instruments and Data Collection System (pages 124-142)

Hemispheric Center for Environmental Technology, Florida International University

Alfredo Ravinet
Edgar Polo
Srinivasa Gadiparthy
Krishnan Raghavan
Steven Becca

International Hurricane Research Center, Florida International University

Ricardo Alvarez
Carolyn Robertson
Scott Caput

Department of Civil Engineering, Clemson University

Timothy Reinhold

3.5 Roof to Wall Connections Subjected to Combined Loads (page 143)

Department of Civil Engineering, Clemson University

Timothy Reinhold
John Lamb

3.6 HLMP Evaluation Project: Focused Survey of the Florida Coastal Monitoring Program (144-155)

Institute for Public Opinion Research, Florida International University

Hugh Gladwin

International Hurricane Research Center, Florida International University

James Rivers
Amy Reid
Deirdra Hazeley
Anthony Peguero

3.7 Workshop to Review, Update and Extend Prior Mitigation Incentives Research and Planning Efforts (pages 156-225)

International Hurricane Research Center, Florida International University

James Rivers
Stefanie Klein
Amy Reid
Juanita Mainster
Lilia Cummingham
Deirdra Hazeley
Anthony Peguero

Department of Landscape Architecture and Urban Planning, Texas A&M University

Walter Gillis Peacock

3.8 Program of Education and Outreach to Convey Benefits of Hurricane Loss Mitigation Devices and Techniques (pages 226-232)

International Hurricane Research Center, Florida International University

Ricardo Alvarez
Carolyn Robertson
Scott Caput
Zuzana Hlavacova
Brie Losego
Victor Camps
Sarah Goodridge
Goldia Robinson-Taylor
Michael Olivero

3.1.a THE EFFECTS OF RESIDENTIAL NEIGHBORHOOD CONFIGURATIONS ON HURRICANE WINDS

The following research examined how different residential neighborhood configurations enhanced or damped hurricane force winds on single-family homes. In Florida, the building code requires architects, structural engineers and manufacturers of building products to meet stringent wind design criteria. The code articulates the necessary minimum wind loads that a building and all the components of its exterior envelope must meet.

The requirements of The Florida Building Code (footnote1) and ASCE 7 (footnote 2) set quantitative wind load parameters for single buildings but do not articulate wind load parameters for groups of buildings. As a result, design professionals are not required to take into account context as a factor in determining wind loads on a single structure. These codes do not distinguish between buildings located in an open field from ones located within dense built- up areas or areas with mature vegetation. These codes assume a worst-case scenario for building wherever it may exist. Yet context must affect wind dynamics. This study examines how three different neighborhood configurations affect wind loads on three different single-family houses.

The neighborhood configurations were selected from prevalent zoning types found in Dade County, Florida. The Dade County Zoning Code (footnote3) sets forth the legal parameters for using a piece of land. It describes what activity may be allowed, how large a structure may be built and where that structure may be located. All three of the zoning types selected for this examination allowed detached, single family homes. These zoning types encompass a full variety of building densities, house typologies and vegetation development.

Three different single-family houses were selected to represent a prevalent range of home configurations found in South Florida. These homes continue work begun in last year’s study “The Interaction of Residential Roof Elements with Hurricane Winds”. These homes depict varying roof heights, roof configurations and plan layouts.

The Neighborhoods

The first neighborhood type to be examined was the zero-lot-line configuration of the Dade County Zoning Code (Case 1) (Figs 1a, 1b, 1c). Of the three neighborhood types selected this one allowed the greatest building density. Lots in this neighborhood are approximately four thousand square feet in size. The allowable building coverage for a house is fifty percent of the total lot size. The setbacks are as follows: twenty feet from the front property line, five feet from the rear property line, zero feet from the zero side and ten feet from the opposite interior side. The maximum building height is thirty-five feet and two stories. The specific neighborhood selected of this zoning type is located along Southwest 110 Terrace in a planned unit development called the Hammocks by the Bay in Dade County, Florida. This particular development consisted of cookie-cutter homes of the same design repeated one right after the other. The uniformity of this development is unique along the neighborhoods examined.

Figure 1a: Aerial Photo

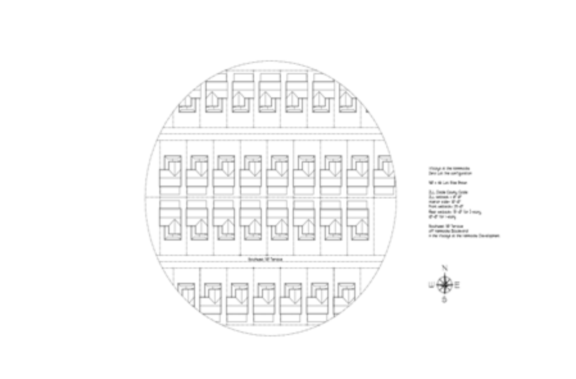


Figure 1b:Neighborhood Site Plan

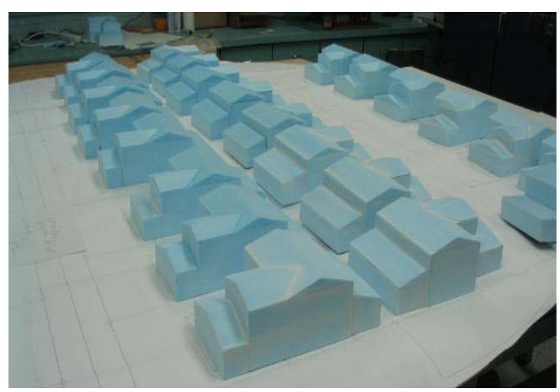


Figure 1c: Model Photo

The second neighborhood type to be examined was an “R” use district in Coral Gables, Dade County (Case 2) (Figs 2a, 2b, 2c). This is the oldest neighborhood development of the three and has the greatest variety of house types and the most mature vegetation. Lots in this neighborhood are approximately five thousand square feet in size. The allowable building coverage is thirty-five percent of the total lot size. The setbacks are as follows: twenty-five feet from the front property line, five feet from the rear property line, and side setbacks totaling twenty percent of the lot width. The maximum building height is thirty-four feet and two and a half stories. The specific neighborhood selected of this zoning type is located at the intersection of Genoa Street and Algeria Avenue in Coral Gables, Florida. This neighborhood has mature trees of a variety of species. As a result, this study includes separate test simulating the tree masses found there. Metal mesh barriers were set up to simulate a permeable tree mass. The house types in this neighborhood are also quite diverse: there are one and two story homes, homes with attached and detached garages, and homes with flat roofs and sloped roofs.

Figure 2a: Aerial Photo

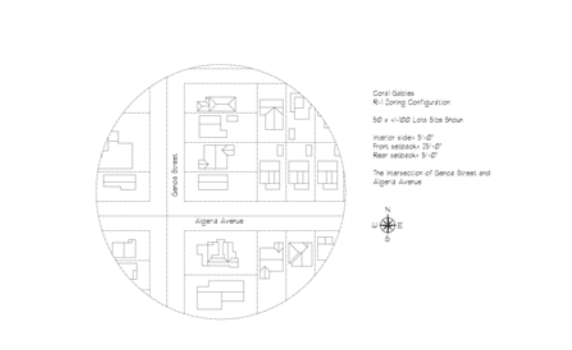


Figure 2b: Neighborhood Site Plan

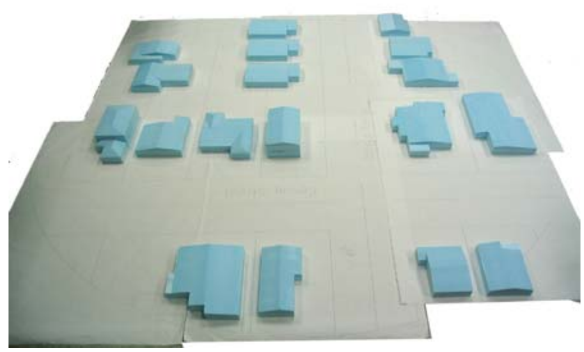


Figure 2c: Model Photo

The third neighborhood is also an “R” use district located in Dade County (Case 3) (Figs 3a, 3b, 3c). This is the least dense neighborhood. Lots in this neighborhood are approximately nine thousand square feet in size. This neighborhood was selected for its cul-de-sac planning. While the two other neighborhoods were planned on orthogonal blocks, this neighborhood is planned around a series of serpentine dead-end roads with turn-a-rounds. Many of the sites are irregular shapes and have large amounts of left over land allowing the houses to be sited well within their required setbacks. The allowable building coverage is thirty-five percent. The setbacks are as follows: twenty-five feet from the front property line, twenty-five feet from the rear property line, and side setbacks of ten percent of the lot width. This specific neighborhood is located along southwest 157 Avenue and 47 Street in Miami-Dade County.

Figure 3a: Aerial Photo

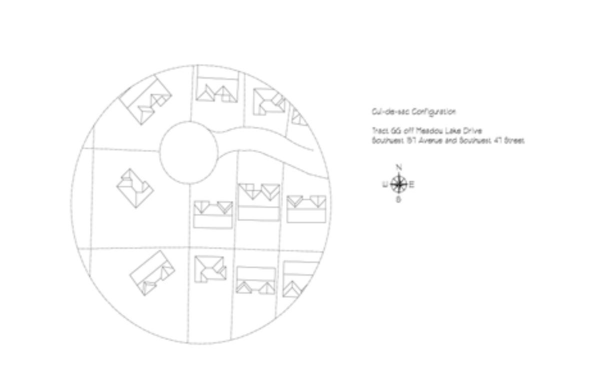


Figure 3b: Neighborhood Site Plan

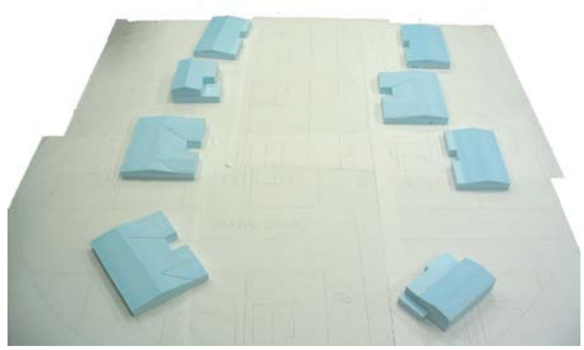


Figure 3c: Model Photo

The Homes

House One, the zero-lot-line house (Figs 4a, 4b, 4c) is the repeated cookie-cutter home found in the zero-lot-line neighborhood. This is a predominately two-story structure with one-story extensions. This home is approximately twenty-two hundred square feet in size. It has a two-car garage within the volume of the house and roof overhangs of one foot. This house has a roof composed of a second-story roof of two perpendicular gables and a first story roof with a front roof gable and a rear shed roof.

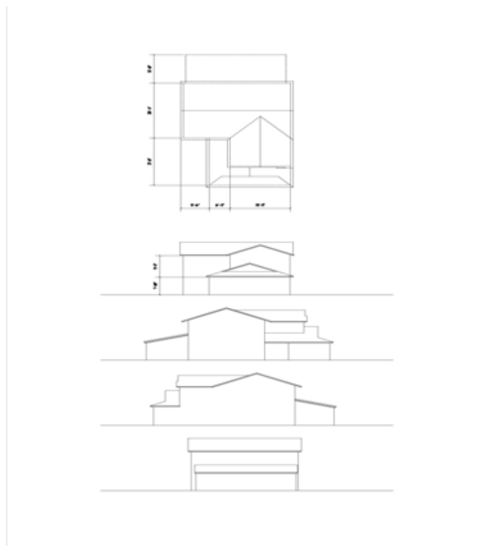
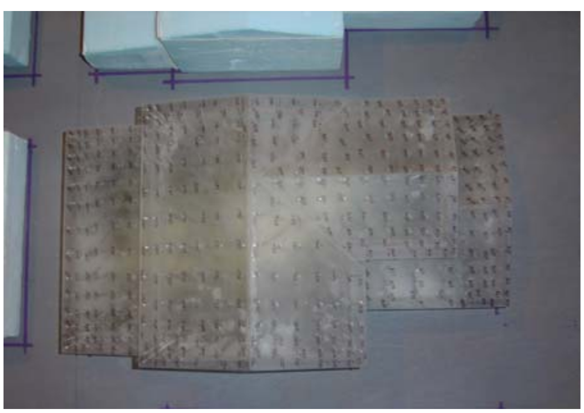


Figure 4a: Plan



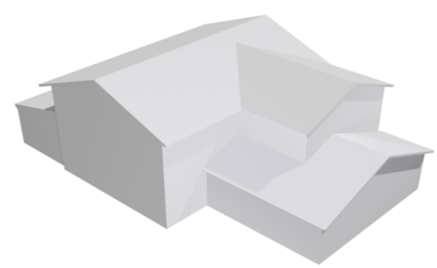


Figure 4b and 4c: Model Photo

House Two is the L-shaped unadorned roof house of last year's study "The Interaction of Residential Roof Elements with Hurricane Winds" (Figs 5a, 5b, 5c). This seventeen hundred square foot, one story, single-family home was developed to represent a typical home in south Florida. All the program of this house fits under the roof. The "L" form was determined to provide the house with roof ridge and valley conditions. The two ends of this home provide the two most typical roof configurations: that of a hip roof and that of a gable end. As roof overhangs are quite prevalent in Florida homes for shade and rain runoff, this house has one-foot, three-foot and five-foot overhangs.

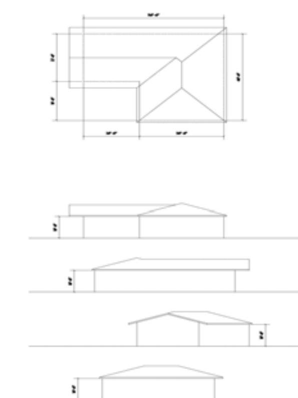
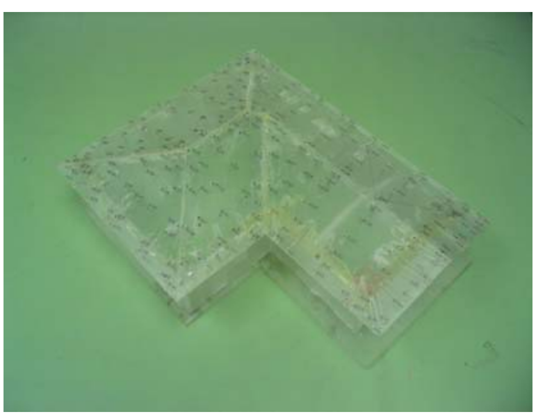


Figure 5a: Plan



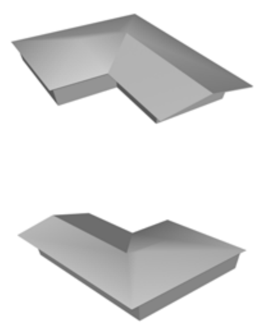


Figure 5b and 5c: Model Photo

House Three is a breezeway house selected as a more complex variation of House Two (Figs 6a, 6b, 6c). This home is split in two by a breezeway, an open covered space often found between the main structure of a house and its garage. This house is approximately nineteen hundred square feet and is comprised of a two-story and one story component. The two-story component represents the living area of the house while the one-story component represents the garage. This house has three-foot overhangs and hip roofs.

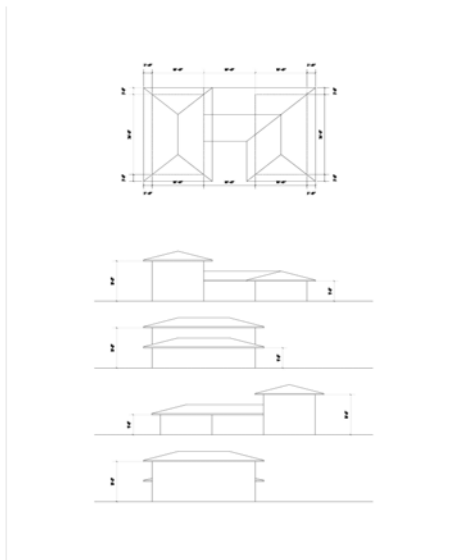


Figure 6a: Plan

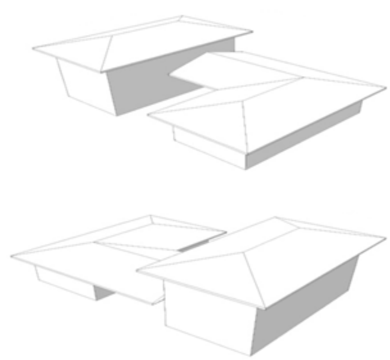


Figure 6b and 6c: Model Photo

Testing

One-quarter inch per square foot Plexiglas scale models of the homes and extruded polyurethane foam models of the neighborhoods were built and tested in a boundary layer wind tunnel at Clemson University under the direction of Dr. Timothy Reinhold. The Plexiglas home models were outfitted with numerous pressure taps located at critical points over the entirety of the roof.

The foam models of the three neighborhood configurations were built to fit on nine-foot wood disks. This disk size was the maximum size that would fit in the boundary layer wind tunnel. At one-quarter inch per foot these disks represent a circular area of approximately three and a third acres. Each Plexiglas model was placed at the center of these neighborhood disks.

The houses were tested individually within five different conditions, open country, open suburban, zero-lot-line neighborhood, Coral Gables neighborhood and cul-de-sac neighborhood. The open country test (Case 4) simulates a wind turbulence of nineteen percent, approximately the condition found if the house were located by itself in an open field. The open suburban test (Case 4) simulates a wind turbulence of twenty-five percent, approximately the condition found if the house were by itself near a suburban context.

Once tested, the maximum and minimum wind pressures at each tap location were recorded and incorporated in an overall pressure map. These pressure maps were then converted into pressure contour maps, which were then graphed on three-dimensional computer models for analysis and comparison.

All the data that is reviewed in this report concerns the reading of positive and negative pressure values on a roof surface. Negative roof pressures represent a pull or suction or uplift on the roof surface while positive roof pressures represent a push on the roof surface. After a review of the initial data, a set of pressure contours was established to organize the different negative and positive pressure tap values. These pressure coefficients on roof surfaces are based on three-second gusts at mean roof height. There are twelve contour values: 1. = above +1.00, 2.+.60 to +1.00, 3 = +.20 to +.60, 4. = -20 to +.20, 5. = -.60 to -.20, 6. = -.00 to -.60, 7. = -.40 to -1.00, 8. =-2.00 to -1.40, 9.= -2.60 to 2.00, 10.=-3.20 to -2.60, 11.= -3.80 to -3.20, 12= -4.40 to -3.80.

House Model One – The Zero-Lot-Line House

The following maps for House One are based on pressure coefficients from Dr. Timothy Reinhold's report, appendix 1, tables of maximum and minimum Pressure Coefficients.

Negative Pressure Maps

Case 1 Zero-Lot-Line Neighborhood

Seven negative pressure contours areas distinguish this map (contours 5 to 11) (Figs 7a, 7b, 7c, 7d). On the second-story roof: high suctions occur along the front gable end and along the front roof edge while low suctions occur in the middle of the roof planes. On the one-story roof: the highest pressures occur on the front gable.

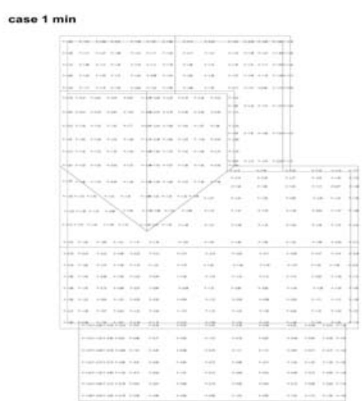


Figure 7a: Pressure Plan

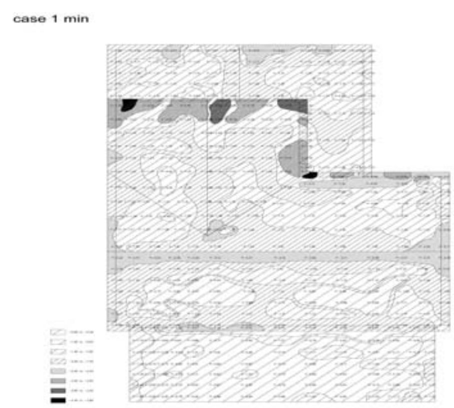


Figure 7b: Roof Pressure Map

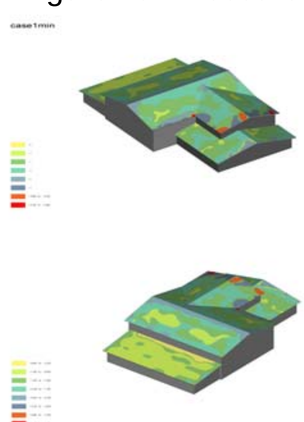


Figure 7c: Roof Pressure Map

Figure 7d: Model Photo

Case 2 Coral Gables Neighborhood

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 8a, 8b, 8c, 8d). On the second-story roof: high suctions occur along all three gables ends and along the front roof edge while low suctions occur in the middle of the roof planes. On the one-story roof: the highest pressures occur on the front gable and on the sloping edges of the shed roof while lower pressures occur in the middle of the shed roof and at the front gable ends.

Figure 8a: Pressure Plan

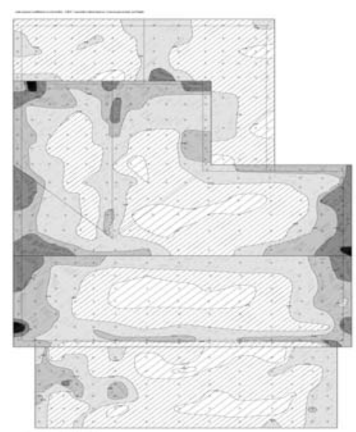


Figure 8b: Roof Pressure Map

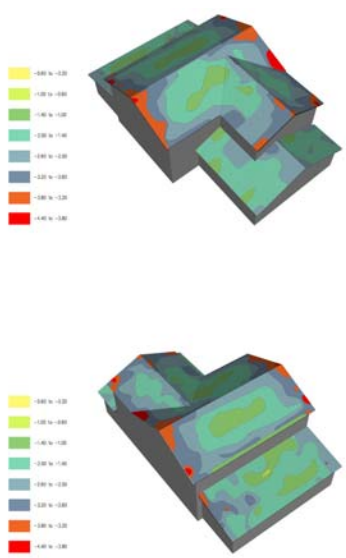


Figure 8c: Roof Pressure Map

Figure 8d: Model Photo

Case 2 Coral Gables Neighborhood with Trees

Six negative pressure contours areas distinguish this map (contours 5 to 10) (Figs 9a, 9b, 9c, 9d). On the second-story roof: high suctions occur along all three gables ends with the side gables having large high suction contour areas. Low suctions occur in the middle of the roof planes. On the one-story roof: the highest pressures occur on the front gable, at its peak and on the sloping edges of the shed roof while lower pressures occur in the middle of the shed roof and at the front gable end that wraps the two-story corner.

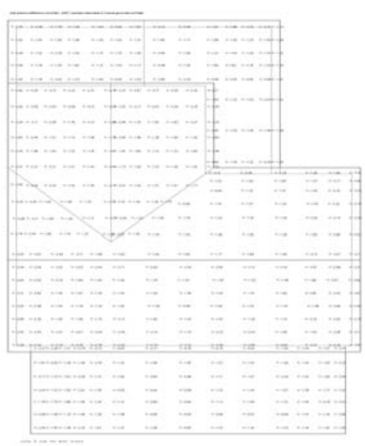


Figure 9a: Pressure Plan

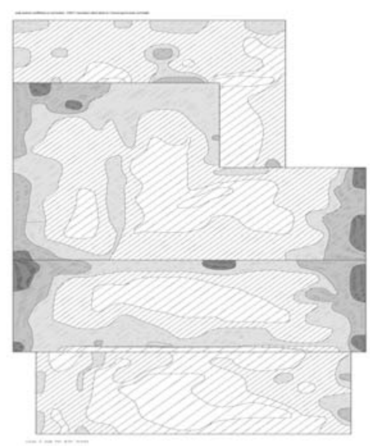


Figure 9b: Roof Pressure Map

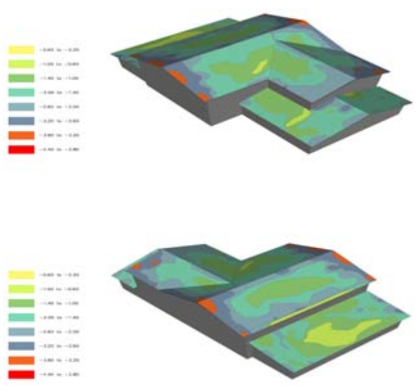


Figure 9c: Roof Pressure Map

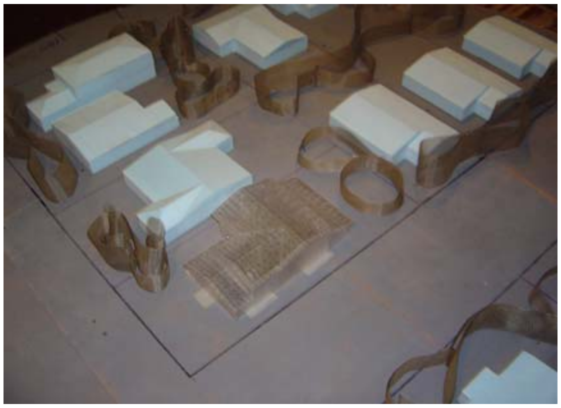


Figure 9d: Model Photo

Case 3 Cul-de-sac Neighborhood

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 10a, 10b,10c,10d). On the second-story roof: high suctions occur along all three gables ends with the side gable nearest to the front gable displaying large high suction contour areas. Low suctions occur in the middle of the roof planes. On the one-story roof: the highest pressures occur on the front gable, at its peak and on the sloping edges of the shed roof while lower pressures occur in the middle of the shed roof and at the front gable ends.

Figure 10a: Pressure Plan

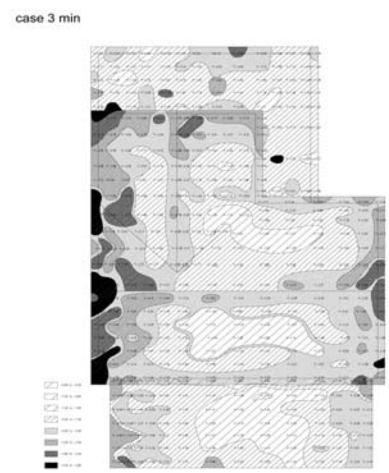


Figure 10b: Roof Pressure Map

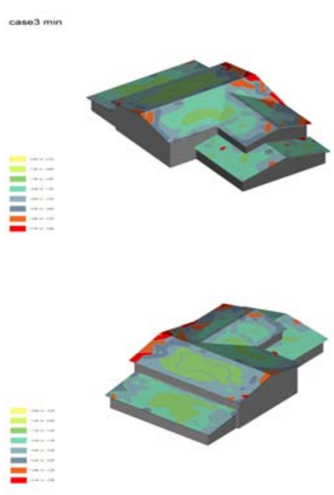


Figure 10c: Roof Pressure Map

Figure 10d: Model Photo

Case 4 Open Country

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 11a, 11b, 11c). On the second-story roof: high suctions occur along all three gables ends with the side gable opposite to the front gable displaying large high suction contour areas. Low suctions occur in the middle of the roof planes. On the one-story roof: the highest pressures occur on the front gable and its edge as it wraps the two-story corner and on the sloping edges of the shed roof while lower pressures occur in the middle of the shed roof and in patches at the front gable ends.

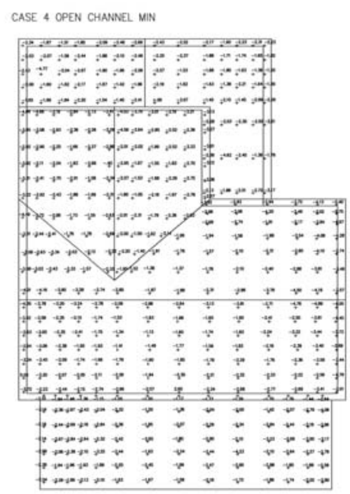


Figure 11a: Pressure Plan

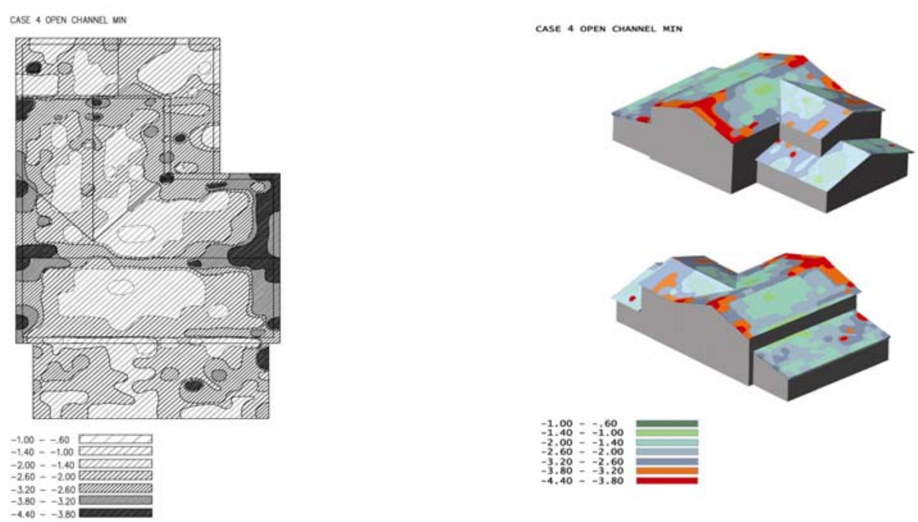


Figure 11b and 11c: Roof Pressure Map

Case 4 Open Suburban

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 12a, 12b, 12c). On the second-story roof: high suctions occur along all three gables ends with the two side gables having the higher suction areas. Low suctions occur in the middle of the roof planes. On the one-story roof: the highest pressures occur on the front gable and its edge as it wraps the two-story corner and on the sloping edges of the shed roof while lower pressures occur in the middle of the shed roof and at the front gable ends.

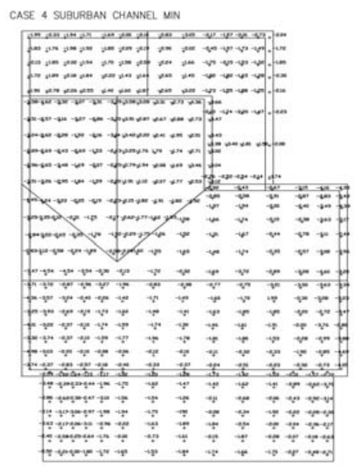


Figure 12a: Pressure Plan

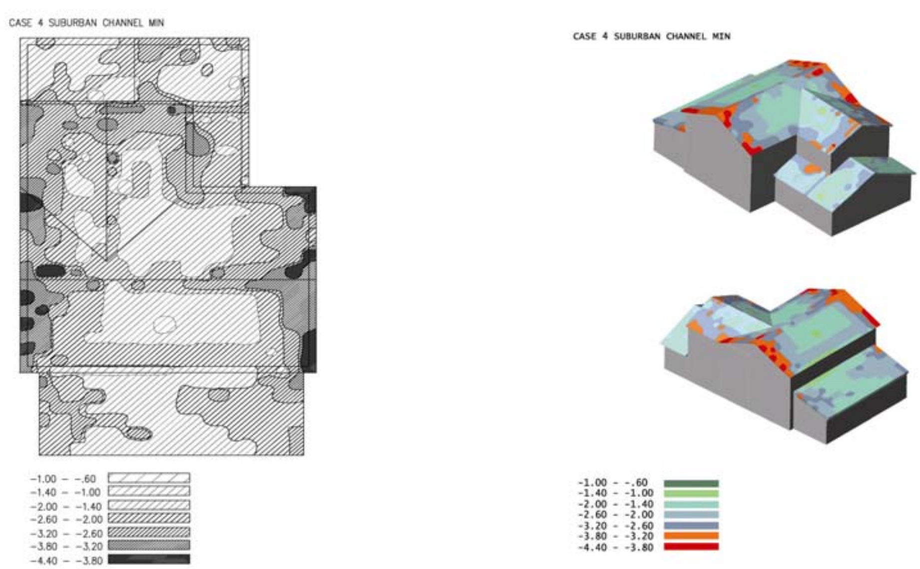


Figure 12b and 12c: Roof Pressure Map

House Model One - Negative Pressure Maps Conclusions

The zero-lot line map remains the standout from the group. It has the smallest areas of high negative pressure contours 9 through 11. These areas are restricted to one gable end. This gable on the second story is the most exposed of the three. The other two gable ends do not register the high negative pressures as the context acts to extrude the roof planes past the house not allowing the wind forces an opportunity to arise. The same condition occurs with the shed roof on the first floor. Low pressures distinguish this area as the context extrudes its geometry disallowing the wind a pocket to create uplift forces. The repetitive nature of the zero-lot-line neighborhood seems to protect the houses within the middle of the block. Exposed ends such as the front gables experience higher uplift pressures but not to the extent found in the four other conditions.

The Coral Gables test without trees exhibits contour patterns found in the cul-de-sac, open country and open suburban testes. It seems this comparatively large mass of the zero-lot-line house in this context leaves it unprotected from high uplift pressures. The map closest to this pressure configuration is the open country test. High uplift pressures occur at the gable ends while low uplift pressures occur at the middle of the roof plane.

When trees are introduced into the Coral Gables context there is a significant reduction in high uplift pressures. This map has no area of extreme negative pressure contour 11. Not only is this pressure contour absent, pressure contour areas 8 through 10 are greatly reduced. It seems that mature tree growth creates protection from high uplift pressure for houses that rise above a lower built context. While this map displays a significant reduction in uplift pressures it does not reduce uplift pressures at the order of magnitude the built environment of the zero-lot-line context does.

The cul-de-sac test displays a pressure contour map similar to the open country and open suburban test with one notable exception. Whereas the open country and open suburban maps have similar high pressures on their side gable ends, the cul-de-sac map has greater uplift pressures on its side gable nearest to the front gable. This variation can be attributed to the placement of the house in the cul-de-sac context. This side gable is exposed while the other side is near a house. It seems this extra area and the angled position of the distant house creates a wedge of space that concentrates wind forces against this gable. This condition is the most volatile condition in the group and as a result, it has the greatest area of negative pressure contour 11.

House Model One – The Zero-Lot-Line House

Positive Pressure Maps

Case 1 Zero-Lot-Line Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 13a, 13b, 13c). On the second-story roof: high positive pressure contours occur along the edge of the roof while low isolated positive pressure contours occur along the roof peak. On the one-story roof: high positive pressure contours occur along the second-story walls behind the front gable and at the top of the shed roof. Lower positive pressure contours occur in localized areas on the front corner of the gable end and at one side of the shed roof.

Figure 13a: Pressure Plan

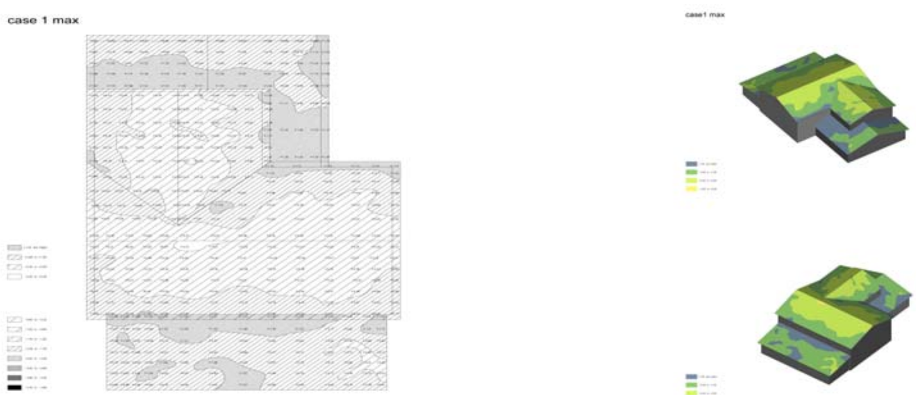


Figure 13b and 13c: Roof Pressure Map

Case 2 Coral Gables Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 14a,14b,14c). On the second-story roof: high positive pressure contours occur along the edge of the roof while low isolated positive pressure contours occur at the roof edge near the gable ends. On the one-story roof: high positive pressure contours occur along the second-story walls behind the front gable and at the top of the shed roof. Lower positive pressure contours occur in a localized area on the shed roof.

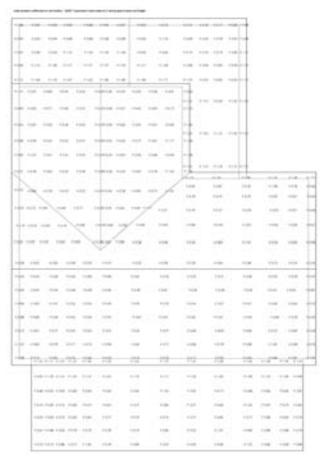


Figure 14a: Pressure Plan

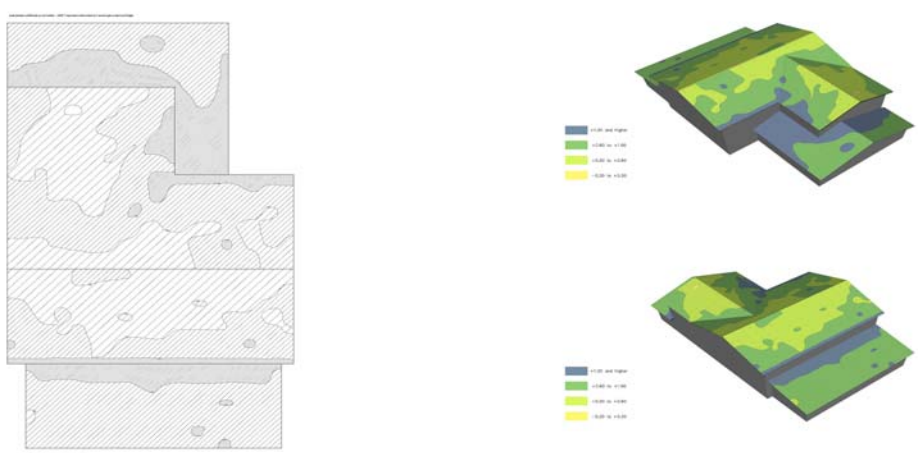
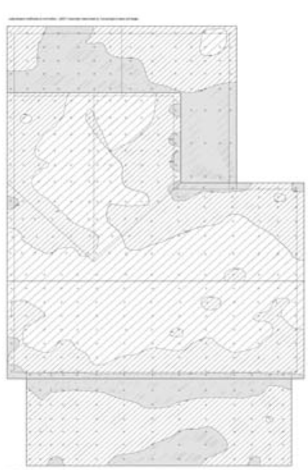


Figure 14b and 14c: Roof Pressure Map

Case 2 Coral Gables Neighborhood with Trees

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 15a, 15b, 15c). On the second-story roof: high positive pressure contours occur along the edge of the roof while low isolated positive pressure contours occur at the roof edge near the gable ends. On the one-story roof: high positive pressure contours occur along the second-story walls behind the front gable, at a section of the gable edge, at the top of the shed roof and at the lower edge of the shed roof. Lower positive pressure contours occur in localized areas at one side of the shed roof and at one corner of the front gable.

Figure 15a: Pressure Plan



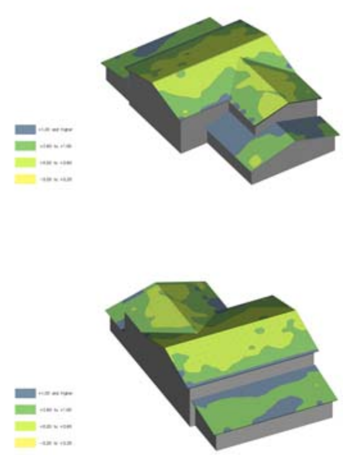
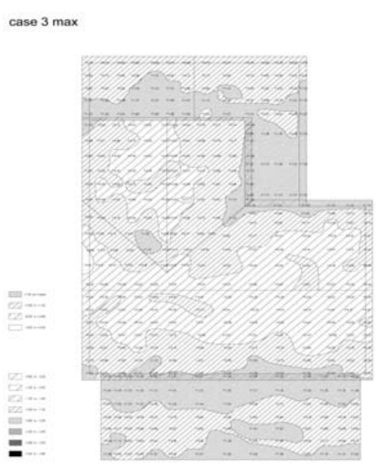


Figure 15b and 15c: Roof Pressure Map

Case 3 Cul-de-sac Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 16a, 16b, 16c). On the second-story roof: high positive pressure contours occur along the edge of the roof while low isolated positive pressure contours occur at the roof edge near the gable ends. On the one-story roof: high positive pressure contours occur along the second-story walls behind the front gable and at the top of the shed roof and all along lower edge of the shed roof. Lower positive pressure contours occur in one localized area at the peak of the front gable.

Figure 16a: Pressure Plan



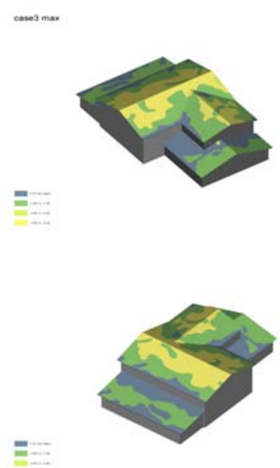


Figure 16b and 16c: Roof Pressure Map

Case 4 Open Country

Three positive pressure contours areas distinguish this map (contours 1 to 3) (Figs 17a, 17b, 17c). On the second-story roof: high positive pressure contours occur along the edge of the roof and up the valley between the front gable and the side gable while lower positive pressure contours occur along the roof peak and the side gables. On the one-story roof: high positive pressure contours occur along the second-story walls behind the front gable and at the top of the shed roof. Lower positive pressure contours occur at the peak of the front gable edge and at the lower edge of the shed roof.

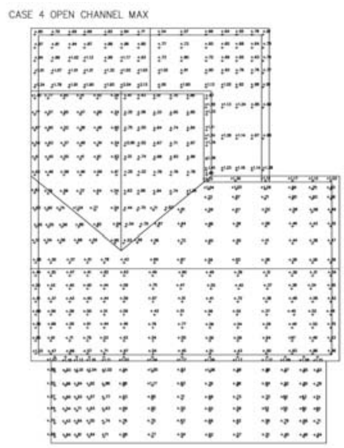
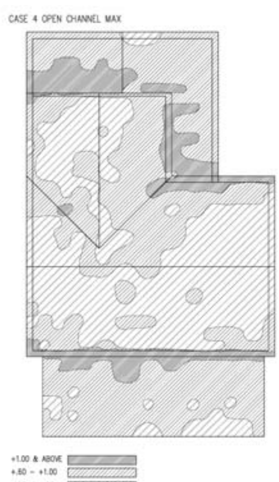


Figure 17a: Pressure Plan



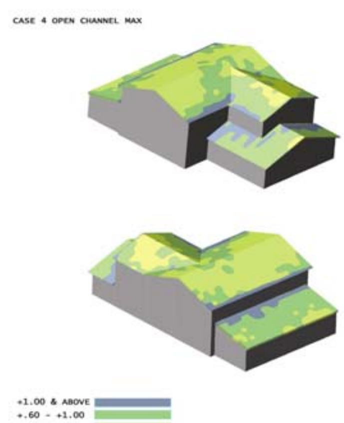


Figure 17b and 17c: Roof Pressure Map

Case 4 Open Suburban

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 18a, 18b, 18c). On the second-story roof: high positive pressure contours occur along the edge of the roof and up both roof valleys while lower positive pressure contours occur in the middle of the roof near the gable ends. On the one-story roof: high positive pressure contours occur along the second-story walls behind the front gable and at the top of the shed roof. Lower positive pressure contours occur in patches in the middle of the shed roof.

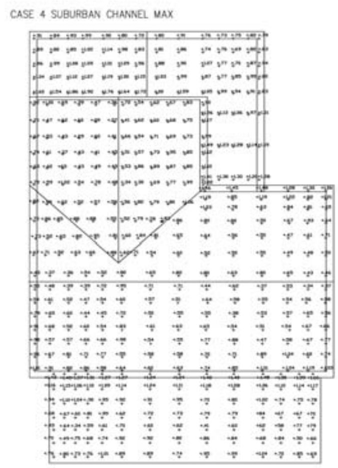


Figure 18a: Pressure Plan

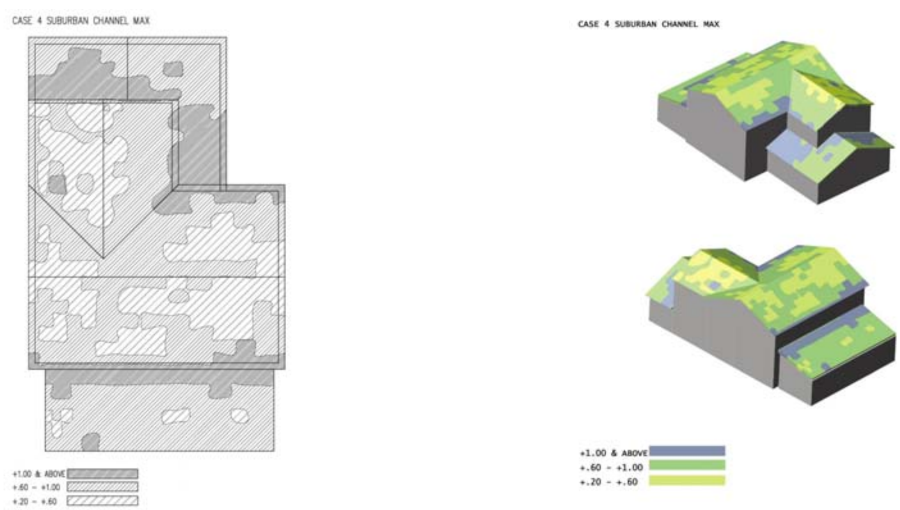


Figure 18b and 18c: Roof Pressure Map

House Model One - Positive Pressure Maps Conclusions

With a series of small exceptions these maps tend to display quite similar pressure maps. All have a distinctive L-shaped high positive pressure contour 1 on the first-story front gable. They all have a linear high positive pressure contour 1 along the top of the first-story shed roof. On the second-story, all the maps have a high positive pressure contour along the lower edge of the side gable facing towards the front. At the ends of the highest peak of the house there is a consistent presence of low positive pressures in all the maps.

The zero-lot-line map and the Coral Gables map with trees both have large areas of low positive pressures at the highest roof peak. The two-story context of the zero-lot-line neighborhood and the mature trees tend to protect this house from extreme positive pressures.

The remaining maps have rather complex contour shapes on the second-story roof. The cul-de-sac map and the open country map display similar patchy pressure contours while the open suburban map has the least amount of low positive pressures. The shed roofs of theses maps are scarcely populated with low positive pressures. When compared to the open country map, the zero-lot-line neighborhood and the Coral Gables neighborhood with trees seem to protect the roofs from high positive pressures while the cul-de-sac neighborhood does not.

House Model Two – The L-shaped One-Story House

The following maps for House Two are based on pressure coefficients from Dr. Timothy Reinhold's report, appendix 2, tables of maximum and minimum Pressure Coefficients.

Negative Pressure Maps

Case 1 Zero-Lot-Line Neighborhood

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 19a, 19b, 19c, 19d). The strongest suction occurs at the gable end with the five-foot overhang. The most extreme suctions occur at the top of this gable while other high suctions occur toward the gables ends. These high pressures are quite isolated. The second highest contour of negative pressure occurs along the gable end and near a hip corner. This pressure map is dominated with generally low negative pressures. The smallest suctions occur at the middle of the roof planes.

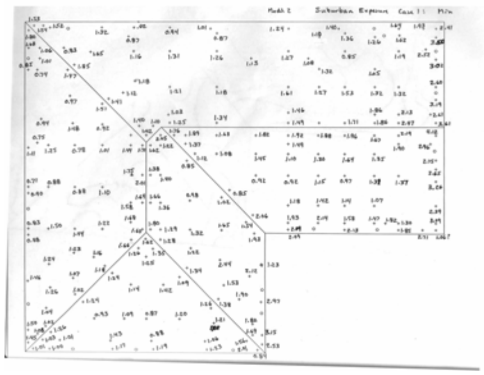


Figure 19a: Pressure Plan

Figure 19b: Roof Pressure Map

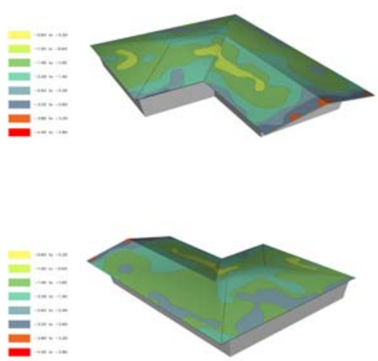


Figure 19c: Roof Pressure Map

Figure 19d: Model Photo

Case 2 Coral Gables Neighborhood

Six negative pressure contour areas distinguish this map (contours 6 to 11) (Figs 20a, 20b, 20c, 20d). The strongest suction occurs at the gable end with the five-foot overhang. The most extreme suctions occur at the top of the gable end while other high suctions occur at the end of the gable, along one middle edge of the hip roof and at the corners of the hip roof. The second highest contour of negative pressure occurs along the gable end, along the hip roof edge, near the hip roof valley and at the hip roof corners. The smallest suctions occur at the middle of the roof planes.

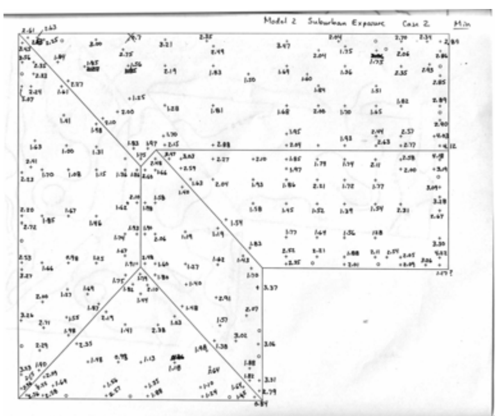


Figure 20a: Pressure Plan

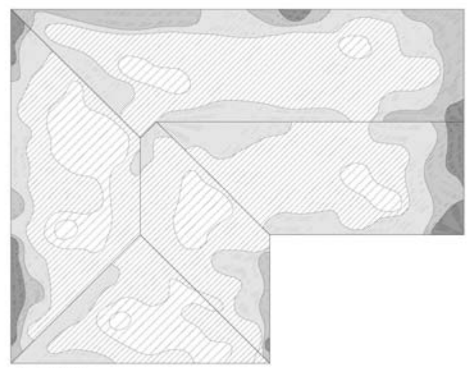


Figure 20b: Roof Pressure Map

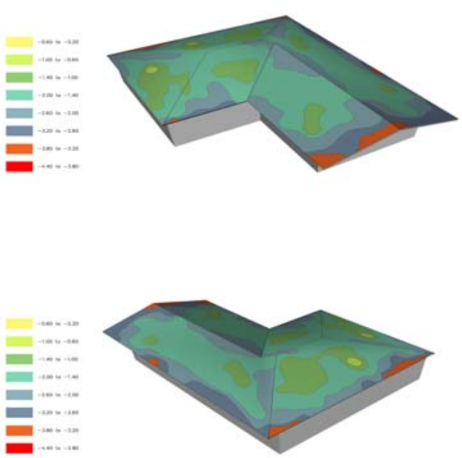


Figure 20c: Roof Pressure Map

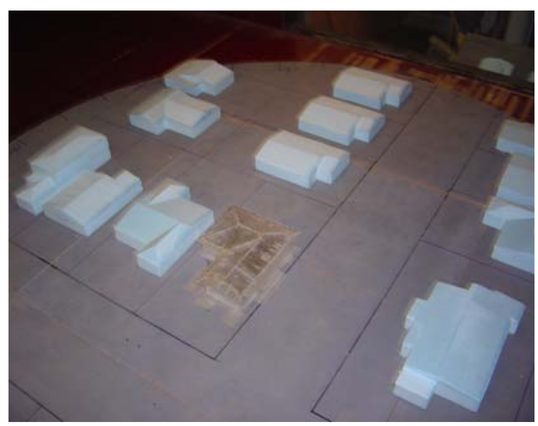


Figure 20d: Model Photo

Case 3 Cul-de-sac Neighborhood

Five negative pressure contour areas distinguish this map (contours 7 to 11) (Fig 21a, 21b, 21c, 21d). The strongest suction occurs at the gable end with the five-foot overhang. The most extreme suctions occur at the top of this gable while other high suctions occur at the gables ends and at one location along the middle edge of the hip roof. The second highest contour of negative pressure occurs along the gable end, along the hip roof edge and near the hip roof valley. The smallest suctions occur at the middle of the roof planes.

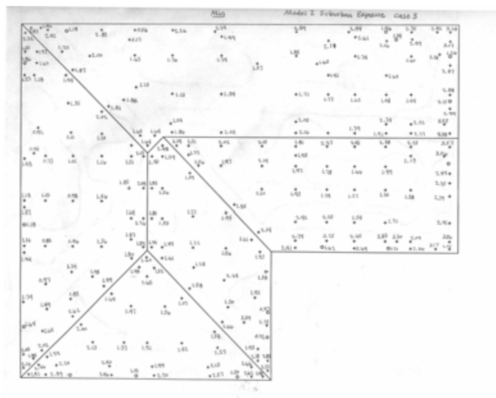


Figure 21a: Pressure Plan

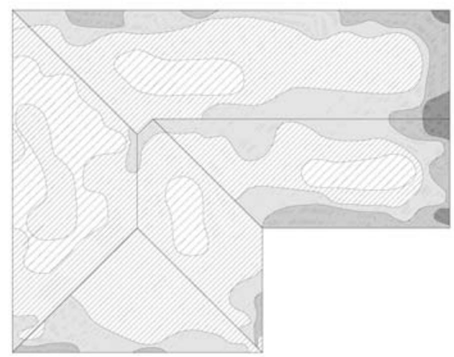


Figure 21b: Roof Pressure Map

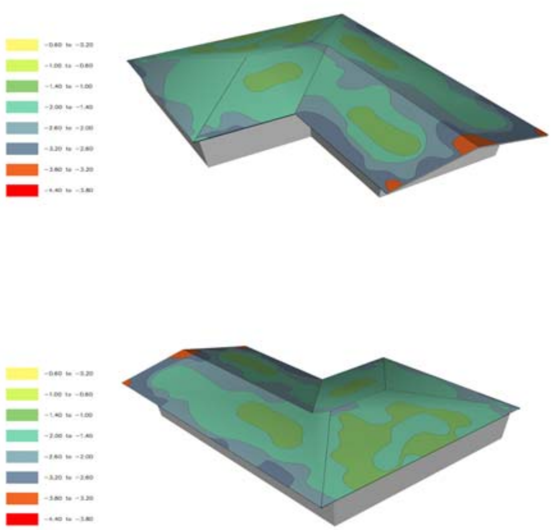


Figure 21c: Roof Pressure Map

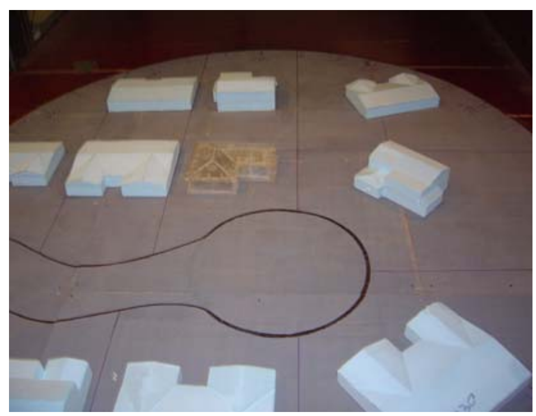


Figure 21d: Model Photo

Case 4 Open Country

Five negative pressure contour areas distinguish this map (contours 7 to 11) (Figs 22a, 22b, 22c). The strongest suction occurs at the gable end with the five-foot overhang. The most extreme suctions occur at the top of this gable while other high suctions occur at the gables ends. The second highest contour of negative pressure occurs along the gable, along the hip roof edge, near the hip roof valley and at the hip roof corners. The smallest suctions occur at the middle of the roof planes.

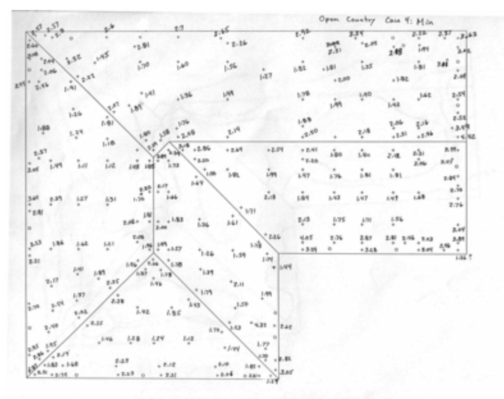


Figure 22a: Pressure Plan

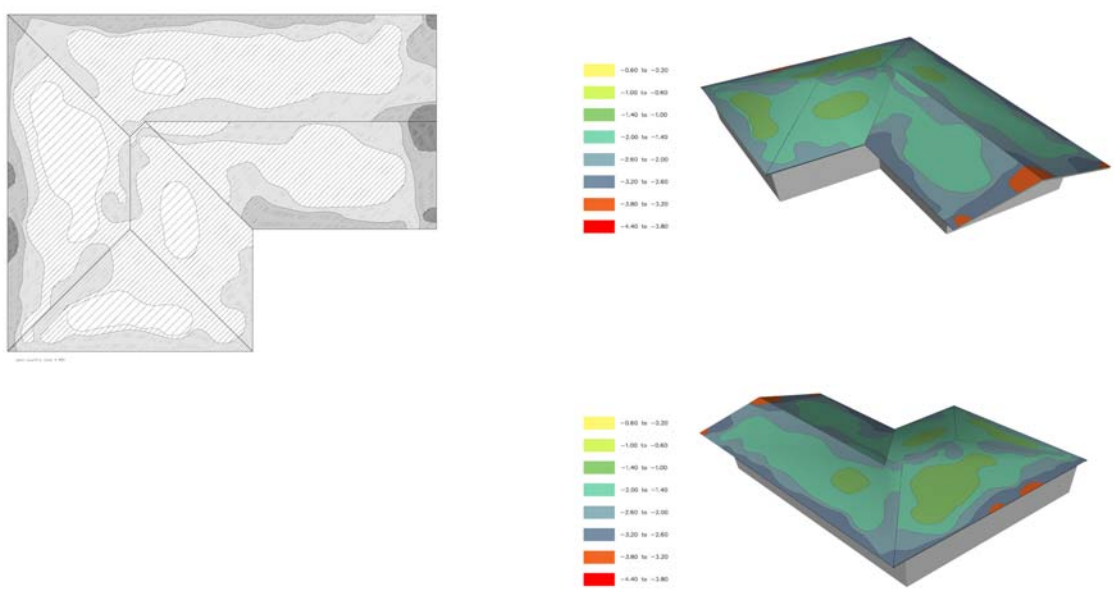


Figure 22b and 22c: Roof Pressure Map

Case 4 Open Suburban

Five negative pressure contour areas distinguish this map (contours 7 to 11) (Figs 23a, 23b, 23c). The strongest suction occurs at the gable end with the five-foot overhang. The most extreme suctions occur at the gable end while other high suctions occur at the top of the gable, along the middle edge of the hip roof and at the corners of the hip roof. The second highest contour of negative pressure occurs along the gable end, along the hip roof edge, near the hip roof valley and at the hip roof corners. The smallest suctions occur at the middle of the roof planes.

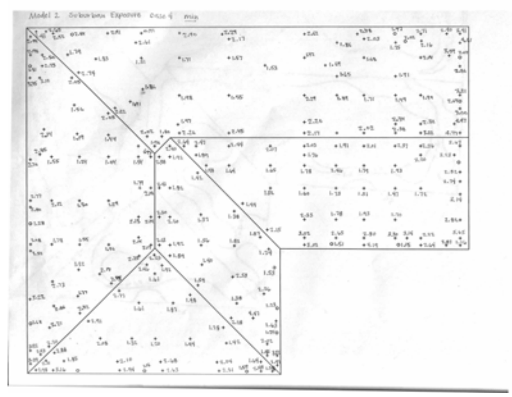


Figure 23a: Pressure Plan

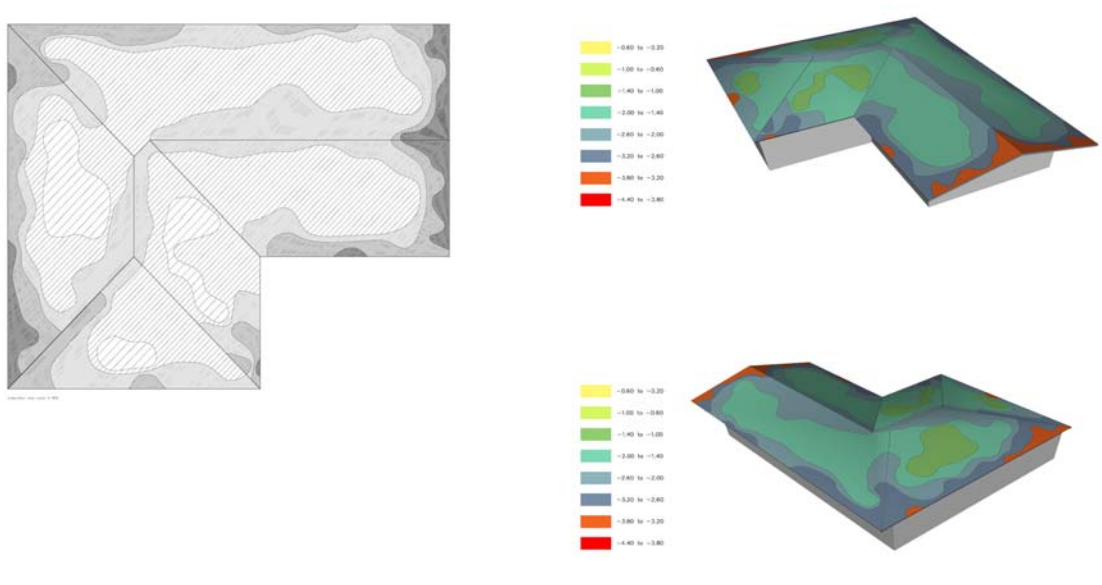


Figure 23b and 23c: Roof Pressure Map

House Model Two - Negative Pressure Maps Conclusions

The pressure map with the greatest variation of this group is the map of case 1, the zero-lot-line neighborhood. While the other maps all have pressure contour 10 along the top of the hip roof this map does not. The extreme pressure contours are isolated in the zero-lot-line map and it is dominated by pressure contours 6 through 8. This can be directly related to the simple fact that this one-story home is surrounded by two-story homes. The two-story context seems to block and protect the home from extreme uplift pressures.

Of the remaining four tests, the Coral Gables map is the only one with the low-pressure contour 6. Its pressure contours 6 through 8 break up and isolate the higher suctions in a way not found in the other three. The Coral Gables neighborhood does have a mix of one and two-story house that seem to be braking up the extreme uplift pressure.

The remaining three test conditions, case 4 open country, case 4 open suburban, and case 3 cul-de-sac neighborhood, all exhibit similar pressure contour configurations. Case 4 open suburban has the greatest areas of high uplift pressure.

House Model Two – The L-shaped One-Story House

Positive Pressure Maps

Case 1 Zero-Lot-Line Neighborhood

Three positive pressure contours areas distinguish this map (contours 1 to 3) (Figs 24a, 24b, 24c). This map is distinguished by the dominance of pressure contour 2.The greater pressures occur towards the overhang edges while the lower pressures occur towards the roof ridges.

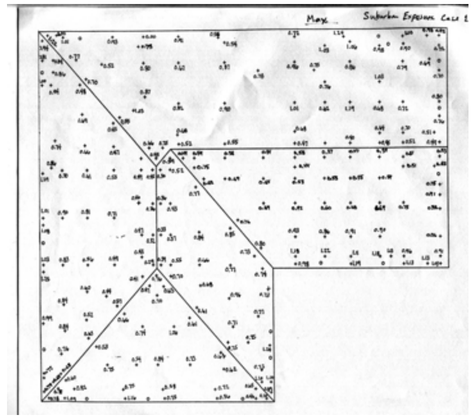


Figure 24a: Pressure Plan

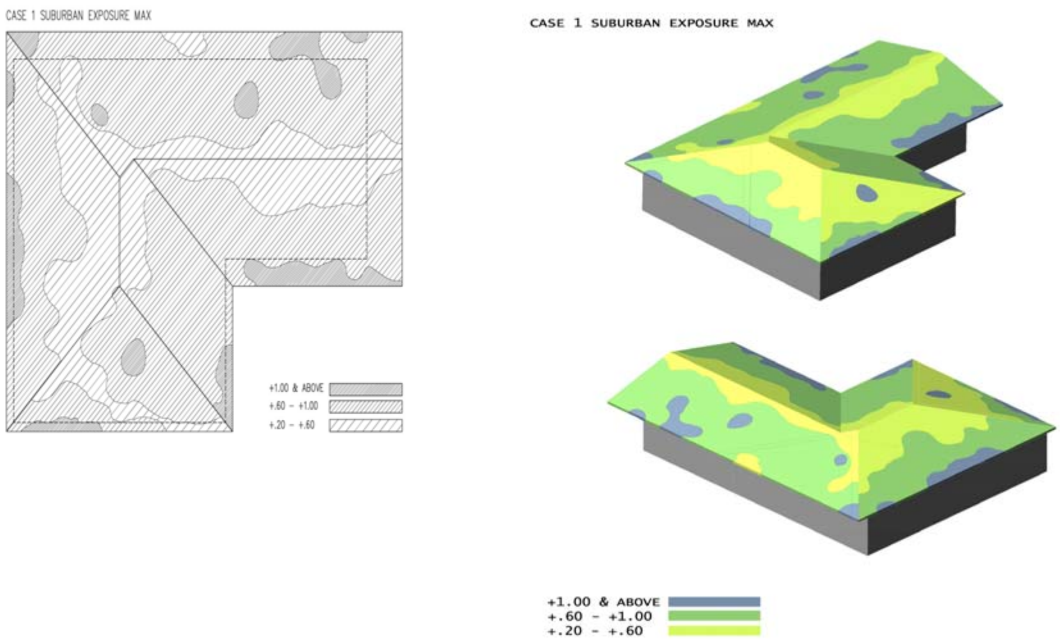


Figure 24b and 24c: Roof Pressure Map

Case 2 Coral Gables Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 25a, 25b, 25c). This map is distinguished by the dominance of pressure contour 3. Pressure contour 2 tends to occur toward the roof edges. Isolated patches of low-pressure contour 4 occur at the roof ridge while the greatest roof pressures occur in small patches along the roof edges.

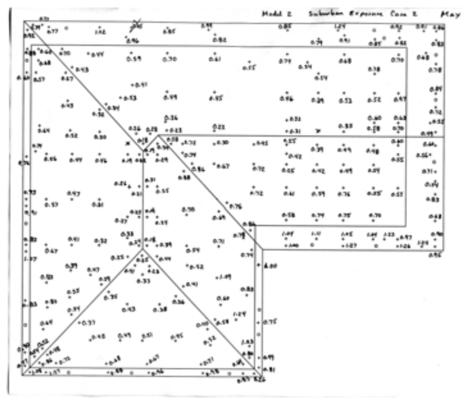


Figure 25a: Pressure Plan

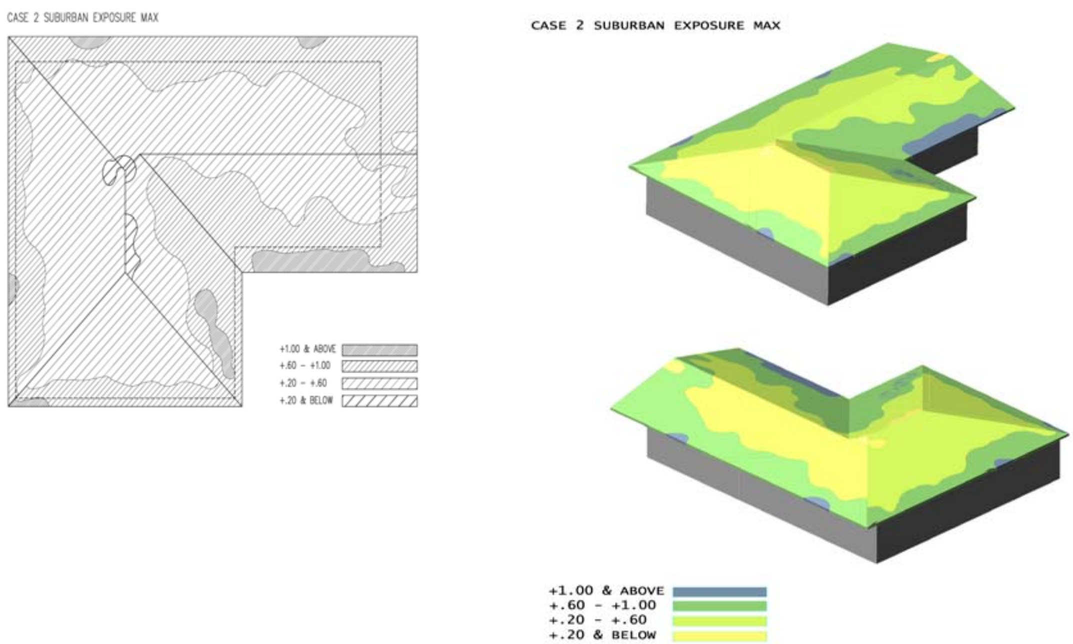


Figure 25b and 25c: Roof Pressure Map

Case 3 Cul-de-sac Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 26a, 26b, 26c). This map is distinguished by the pressure contour 3 and pressure contour 2. The greater pressures occur towards the overhang edges while the lower pressures occur towards the roof ridges. Isolated patches of low-pressure contour 4 occur at the roof ridge while the greatest roof pressures occur in small patches along the roof edges.

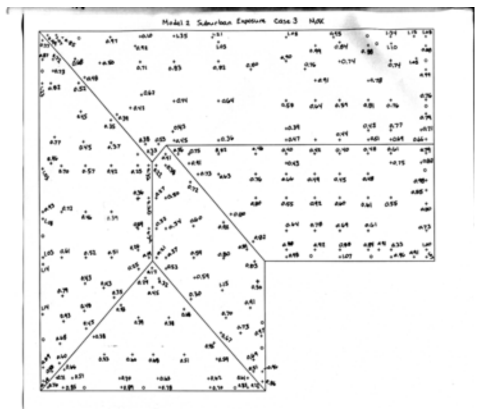
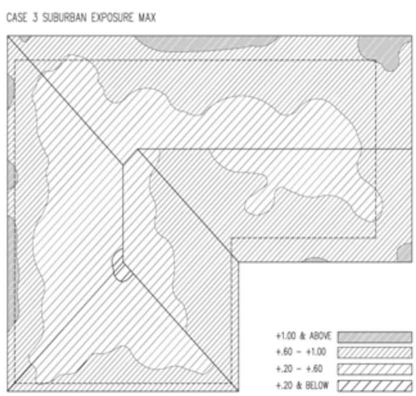


Figure 26a: Pressure Plan



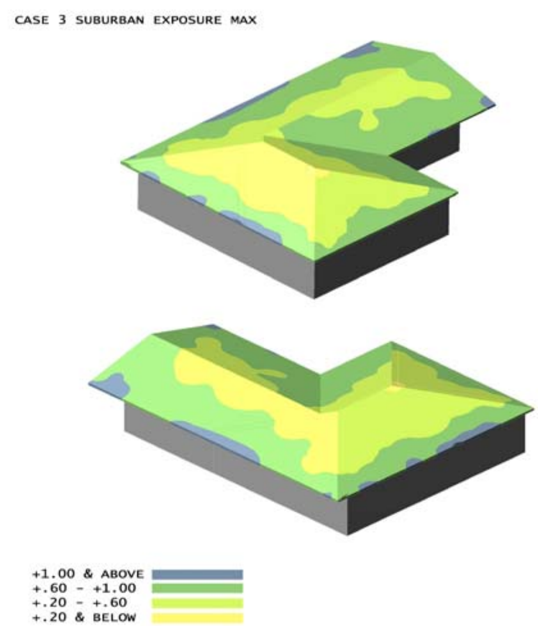


Figure 26b and 26c: Roof Pressure Map

Case 4 Open Country

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 27a, 27b ,27c). This map is distinguished by the pressure contour 3 and pressure contour 2. The greater pressures occur towards the overhang edges while the lower pressures occur towards the roof ridges. A significant low-pressure contour 4 occurs along the roof ridge while the greatest roof pressures occur in two patches along the roof edges near the corners.

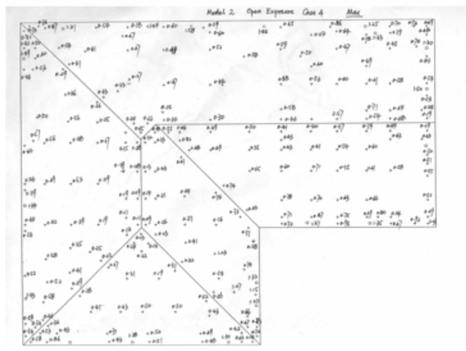


Figure 27a: Pressure Plan

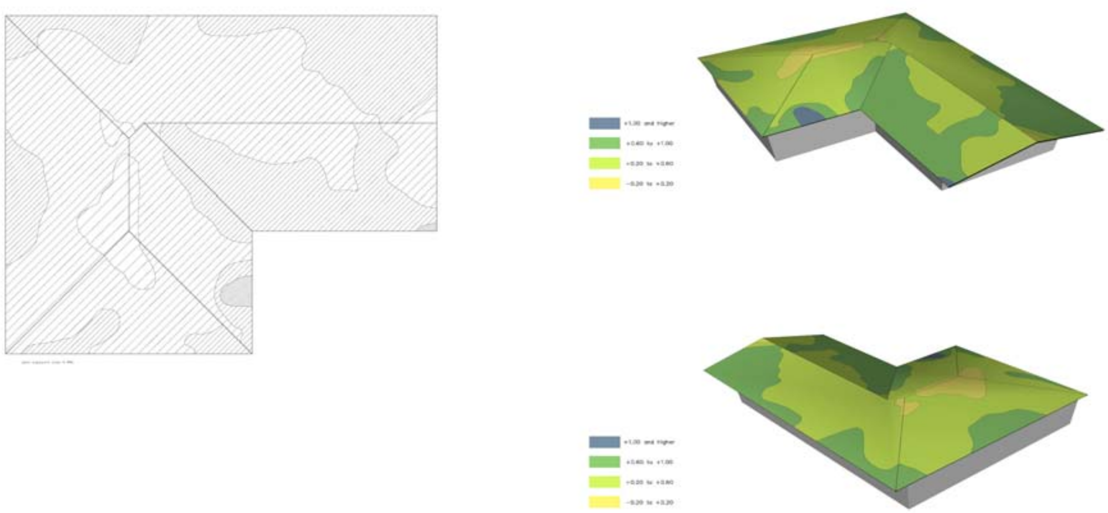


Figure 27b and 27c: Roof Pressure Map

Case 4 Open Suburban

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 28a, 28b, 28c). This map is distinguished by the pressure contour 3 and pressure contour 2. The greater pressures occur towards the overhang edges while the lower pressures occur towards the roof ridges. A low-pressure contour 4 occurs along the roof ridge while the greatest roof pressures occur in five patches along the roof edges near the corners.

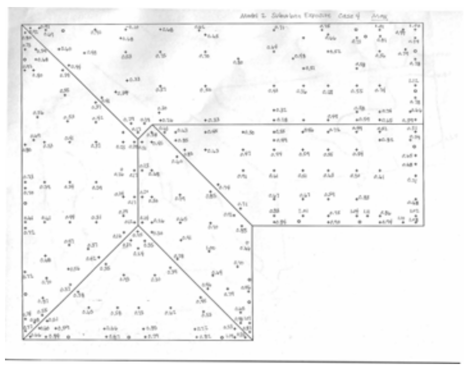


Figure 28a: Pressure Plan

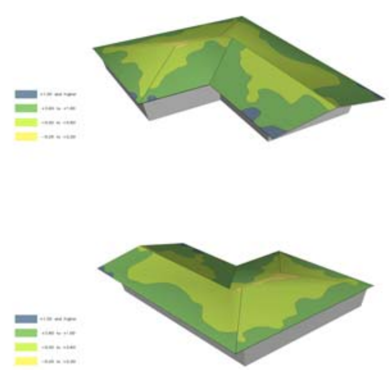


Figure 28b and 28c: Roof Pressure Map

House Model Two - Positive Pressure Maps Conclusions

Here again the zero-lot-line condition provides the greatest variation from the group. It is the only positive pressure map without any pressures below +20. In addition, this map displays the smallest pressure contour 3 and the largest amount of pressures above +1.00. In comparison to the open country map, the positives pressures found on the zero-lot-line map are dramatically greater. It seems that the second story context around this one story house has caused greater positive pressures on the roof.

The remaining three maps, the open suburban, the Coral Gables neighborhood and the cul-de-sac neighborhood maps are quite similar. They all display the same range of positive pressure and a similar layout of pressure contours.

House Model Three – The Breezeway House

The following maps for House Three are based on pressure coefficients from Dr. Timothy Reinhold's report, appendix 3, tables of maximum and minimum Pressure Coefficients.

Negative Pressure Maps

Case 1 Zero-Lot-Line Neighborhood

Four negative pressure contours areas distinguish this map (contours 6 to 9) (Figs 29a, 29b, 29c, 29d). The strongest suction occurs at the top of the second-story hip roof and at one corner. Additional strong suctions occur at the top of the one-story hip roof. The second highest contour of negative pressure occurs along the top of the second floor roof ridge, at its corners, along the first story roof ridge and in the middle of the roof plane. The smallest suctions occur throughout the second-story roof, at its edges and in the middle of the roof planes. These low suctions also occur throughout the first-story roof.

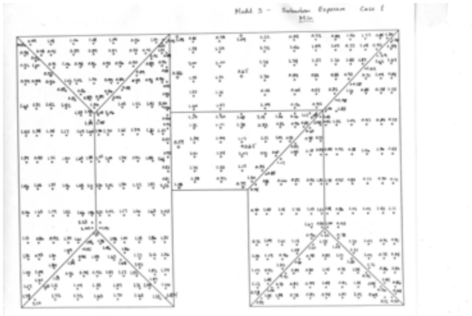


Figure 29a: Pressure Plan

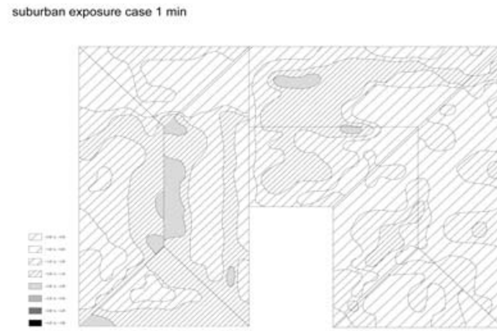


Figure 29b: Roof Pressure Map

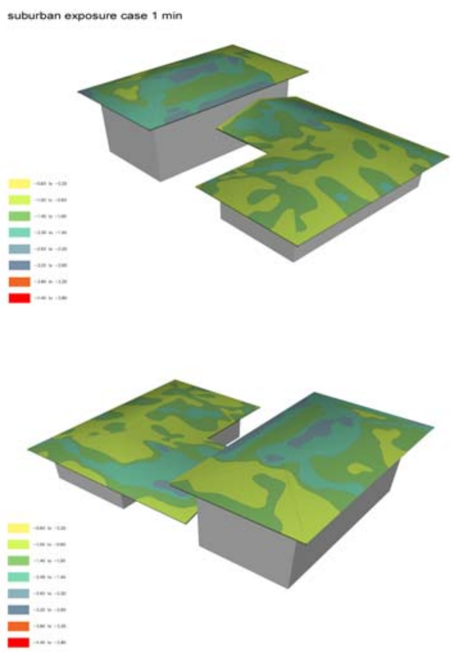


Figure 29c: Roof Pressure Map

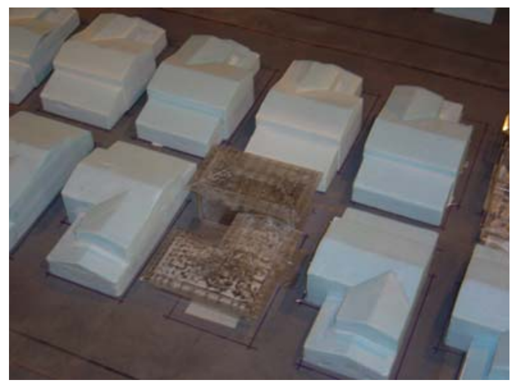


Figure 29d: Model Photo

Case 2 Coral Gables Neighborhood

Five negative pressure contours areas distinguish this map (contours 6 to 10) (Figs 30a, 30b, 30c, 30d). On the second-story roof: high suctions occur along the roof edge and at its peak while low suctions occur in the middle of the roof planes. On the one-story roof: high suctions occur at the roof edge while low suctions occur in the middle of the roof plane.

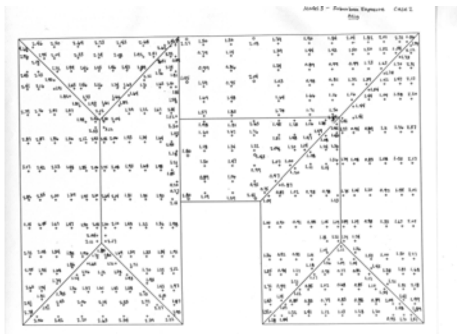


Figure 30a: Pressure Plan

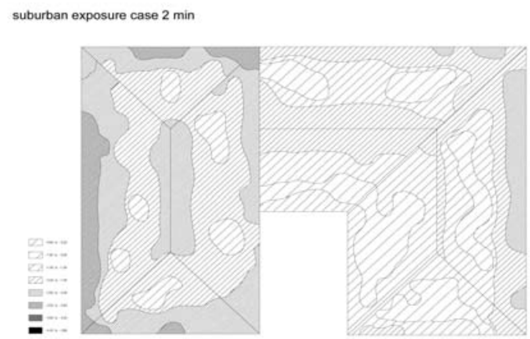


Figure 30b: Roof Pressure Map

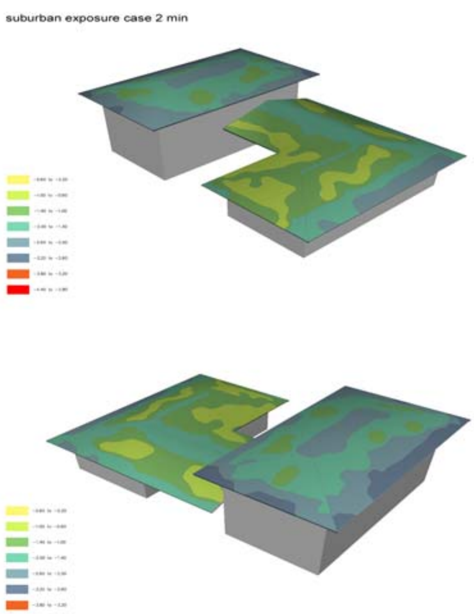


Figure 30c: Roof Pressure Map

Figure 30d: Model Photo

Case 3 Cul-de-sac Neighborhood

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 31a, 31b, 31c, 31d). On the second-story roof: high suctions occur along the roof edge and at its peak with some extreme suctions at one corner while low suctions occur in the middle of the roof planes. On the one-story roof: high suctions occur at the roof edge while low suctions occur in the middle of the roof plane.

Figure 31a: Pressure Plan

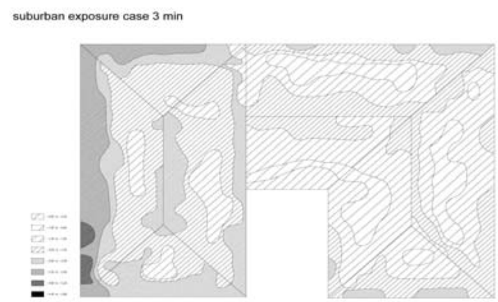


Figure 31b: Roof Pressure Map

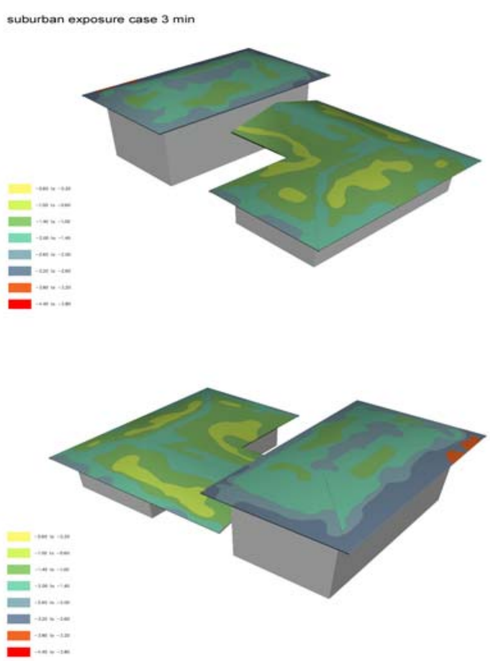


Figure 31c: Roof Pressure Map

Figure 31d: Model Photo

Case 4 Open Country

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 32a, 32b, 32c). On the second-story roof: high suctions occur along the roof edge, at its peak with some extreme suctions at two corners and at one roof edge. Low suctions occur in the middle of the roof planes. On the one-story roof: high suctions occur at the roof edge while low suctions occur in the middle of the roof plane.

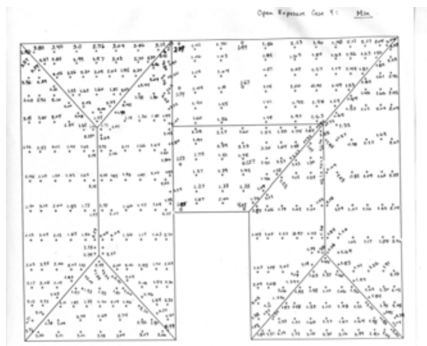


Figure 32a: Pressure Plan

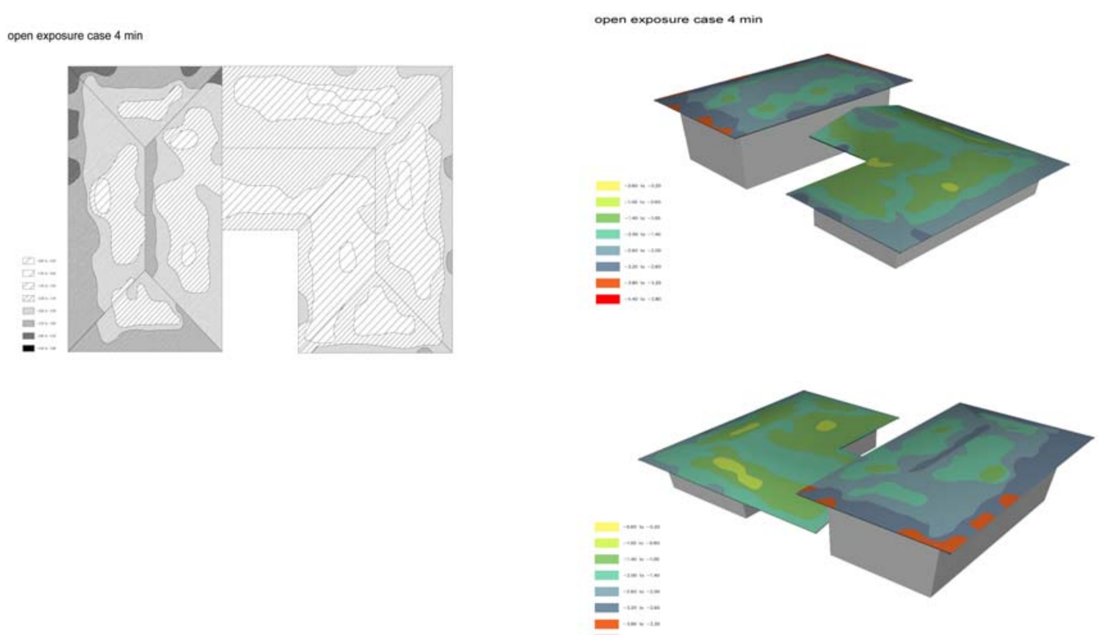


Figure 32b and 32c: Roof Pressure Map

Case 4 Open Suburban

Six negative pressure contours areas distinguish this map (contours 6 to 11) (Figs 33a, 33b, 33c). On the second-story roof: high suctions occur along the roof edge and at its peak with extreme suctions occurring on three sides of the roof edge while low suctions occur in the middle of the roof planes. On the one-story roof: high suctions occur at the roof edge and along the roof peak while low suctions occur in the middle of the roof plane.

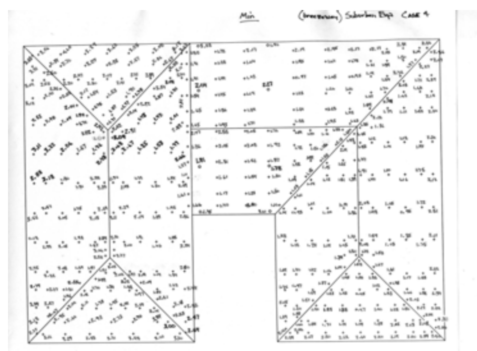


Figure 33a: Pressure Plan

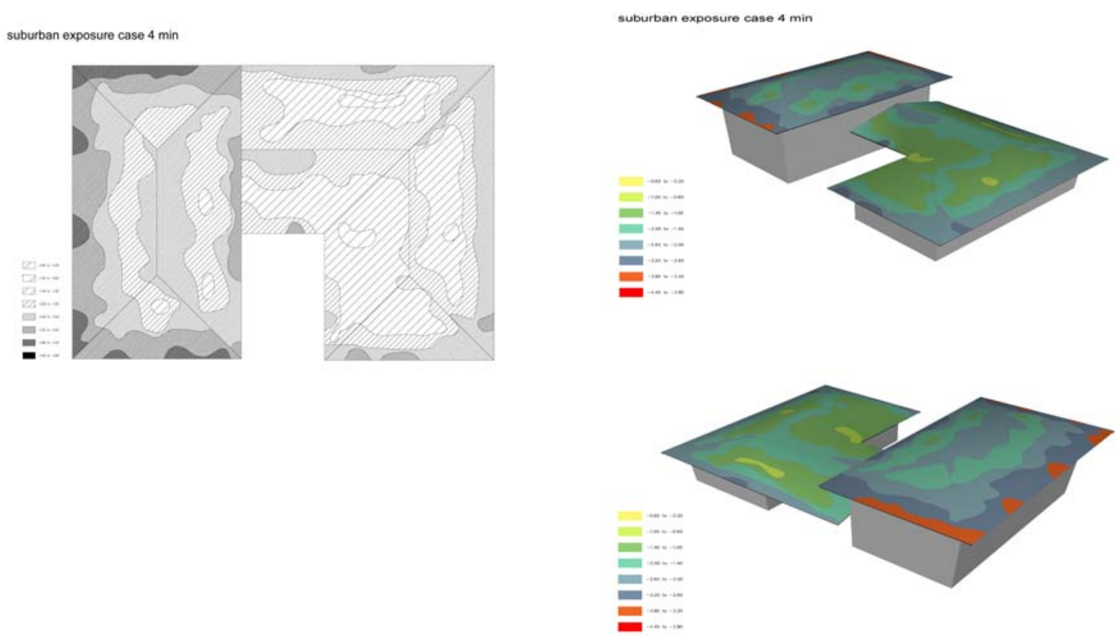


Figure 33b and 33c: Roof Pressure Map

House Model Three - Negative Pressure Maps Conclusions

The zero-lot-line neighborhood exhibits the lowest overall uplift pressures for this roof. It is distinguished by only four pressure contours (6 to 9) while the other tests exhibit five or six. The two-story context of the zero-lot-line neighborhood again seems to protect the house from high suctions. The second-story roof does have slightly higher suctions than the first but not at a significantly higher order of magnitude.

The Coral Gables neighborhood test also reveals that the context seems to be protecting the roof from higher uplift pressures but not to the extent the zero-lot-line neighborhood did. The higher uplift pressure contour 10 appears on this map on the second-story roof only. The first-story roof has the same number of pressure contours as the zero-lot-line map. Even though the Coral Gables context is made up of a mix of one and two-story homes it still manages to brake up stronger uplift pressures.

The cul-de-sac neighborhood test shares the same number of pressure contours as the open country and open suburban tests. It does however, have a significantly smaller high-pressure contour 11 area than these two. While the cul-de-sac neighborhood does not protect from high uplift pressure as the zero-lot-line and the Coral Gables neighborhood do; it does manage to reduce these pressures slightly.

The open country and open suburban tests reveal that the second floor roof is more susceptible to higher uplift pressures than the one-story roof. It exhibits a full range of pressure contours 6 to 11 while the one-story roof has a range of 6 to 10.

House Model Three – The Breezeway House

Positive Pressure Maps

Case 1 Zero-Lot-Line Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 34a, 34b, 34c). On the second-story roof: high positive pressure contours occur in isolated patches near the edge of the roof while low positive pressure contours occur at the ends of the roof peak. On the one-story roof: one isolated high positive pressure contour occurs in the middle of the roof plane while low positive pressure contours occur at the wall of the two-story section, at the top of the roof peak and at one edge.

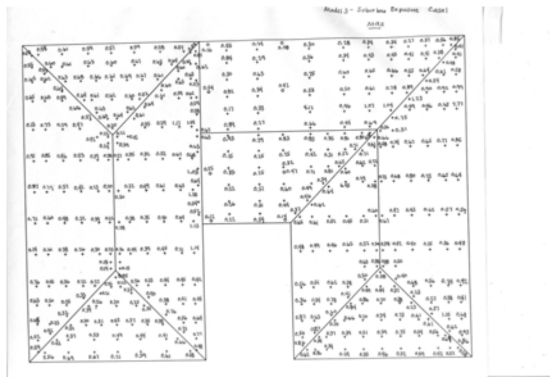


Figure 34a: Pressure Plan

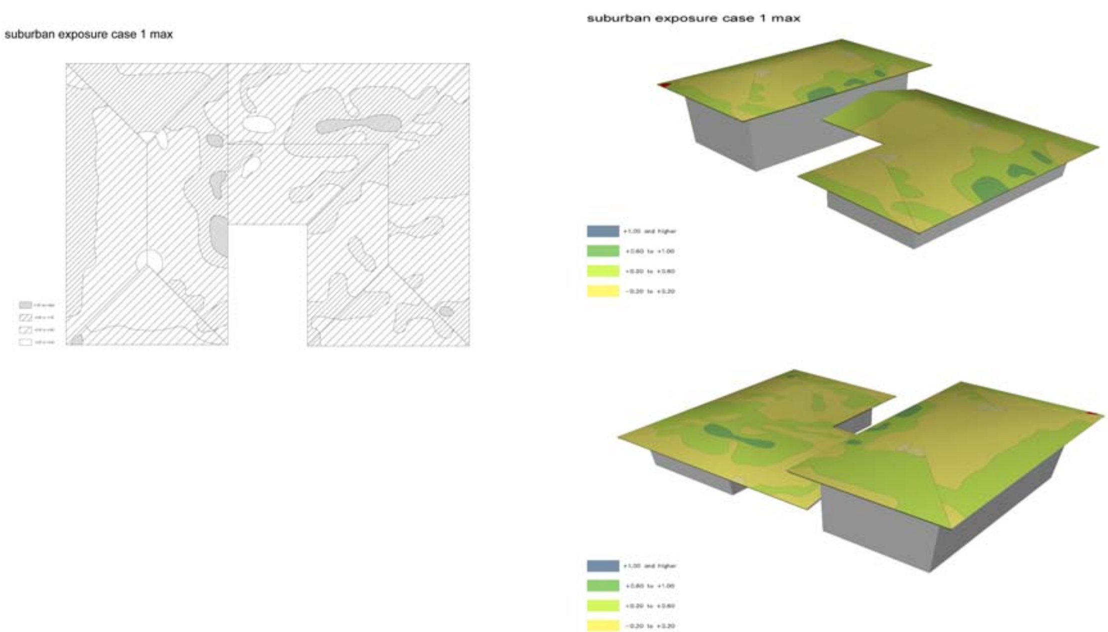


Figure 34b and 34c: Roof Pressure Map

Case 2 Coral Gables Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 35a, 35b, 35c). On the second-story roof: high positive pressure contours occur in one isolated patch near the edge of the roof just above the breezeway while low a positive pressure contours occurs at one end of the roof peak. On the one-story roof: high positive pressure contours occur above the breezeway particularly near the roof edge, in its valley and along the wall of the two-story section. Lower positive pressure contours occur on the opposite side of the roof away from the breezeway.

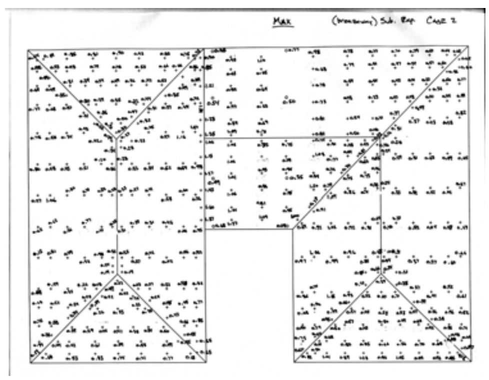


Figure 35a: Pressure Plan

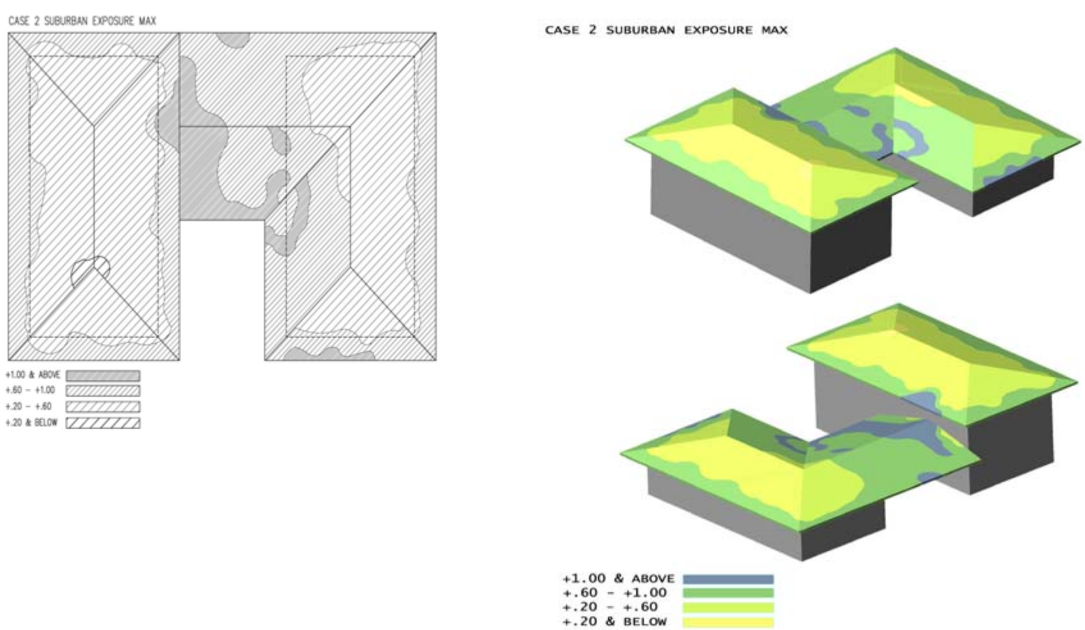


Figure 35b and 35c: Roof Pressure Map

Case 3 Cul-de-sac Neighborhood

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 36a, 36b, 36c). On the second-story roof: high positive pressure contours occur in isolated patches near the edge of the roof just opposite the breezeway while low isolated positive pressure contours occur at one end and at the middle of the roof peak. On the one-story roof: high positive pressure contours occur above the breezeway near the roof edge, up its valley and in isolated patches along the roof edge. Lower positive pressure contours occur along the roof ridge and on the roof plane away from the breezeway.

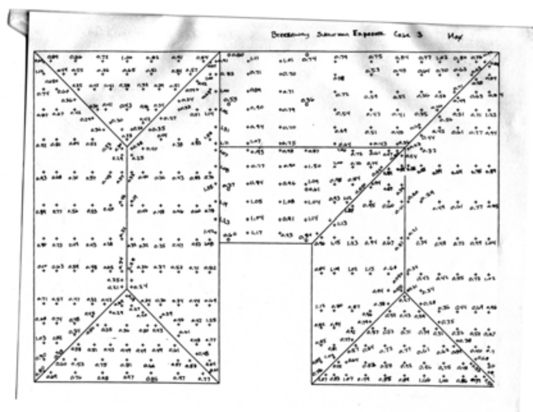


Figure 36a: Pressure Plan

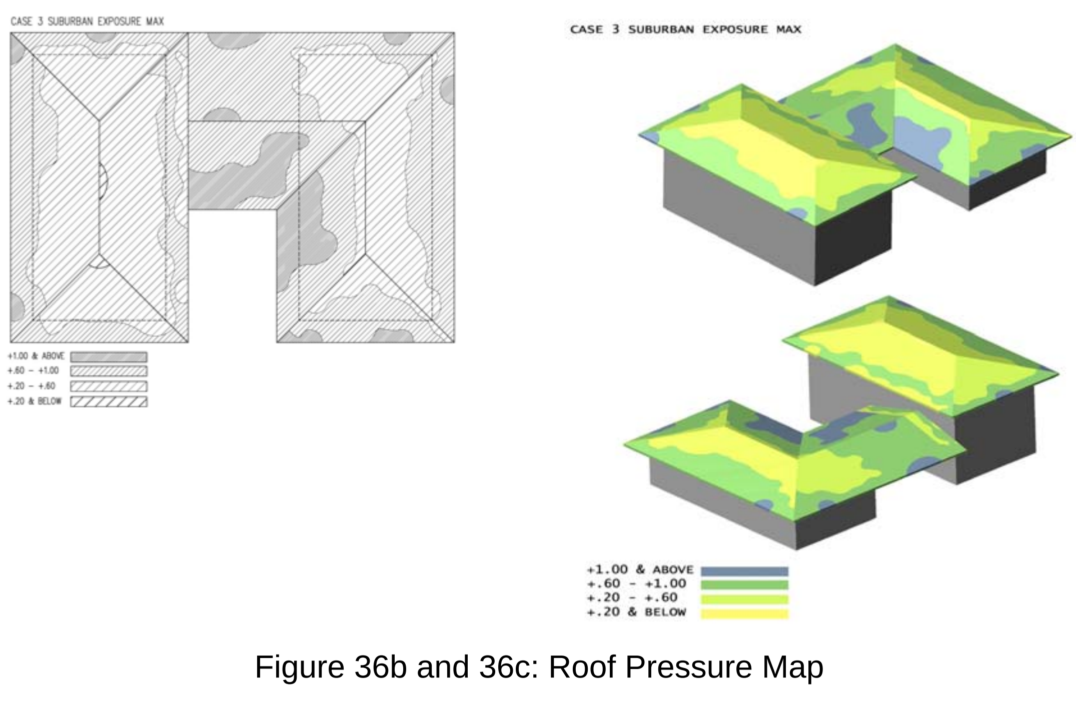


Figure 36b and 36c: Roof Pressure Map

Case 4 Open Country

Four positive pressure contours areas distinguish this map (contours 1 to 4) (Figs 37a, 37b, 37c). On the second-story roof: high positive pressure contours occur along the edge of the roof just above the breezeway while low isolated positive pressure contours occur along the roof peak. On the one-story roof: high positive pressure contours occur in a concentrated area above the breezeway near the roof edge and up its valley. Lower positive pressure contours occur along the roof ridge and on the roof plane away from the breezeway.

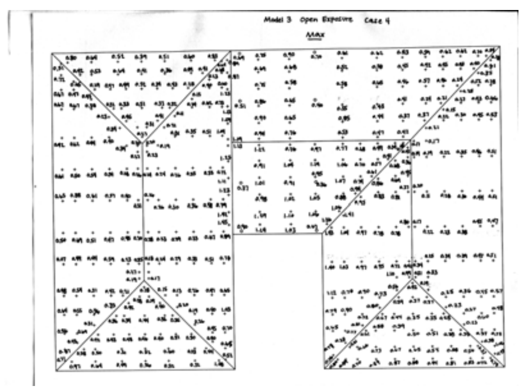


Figure 37a: Pressure Plan

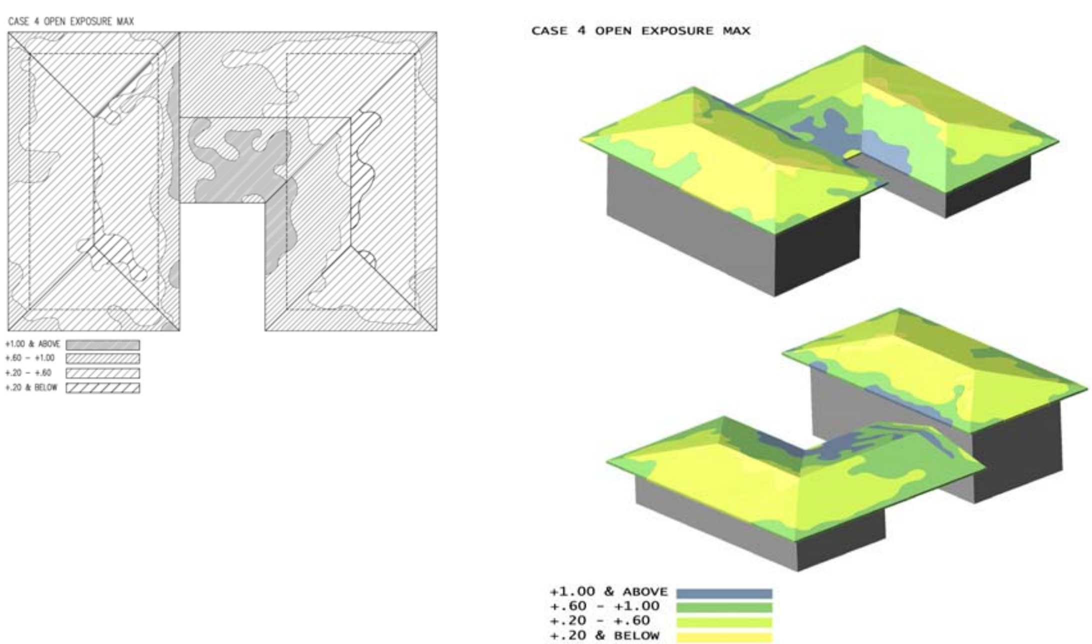


Figure 37b and 37c: Roof Pressure Map

Case 4 Open Suburban

Three positive pressure contours areas distinguish this map (contours 1 to 3) (Figs 38a, 38b, 38c). Low-pressure contour 4 does not appear on this map. On the second-story roof: high positive pressure contours occur along the edge of the roof just above the breezeway and at an isolated corner away from the breezeway while a low positive pressure contour 3 dominates the remaining middle area of the roof. On the one-story roof: high positive pressure contours occur in a concentrated area above the breezeway near the roof edge, along the second story wall and up its valley with one remote high pressure patch occurring on the opposite roof plane above the breezeway. The low positive pressure contour 3 dominates the roof plane opposite the breezeway.

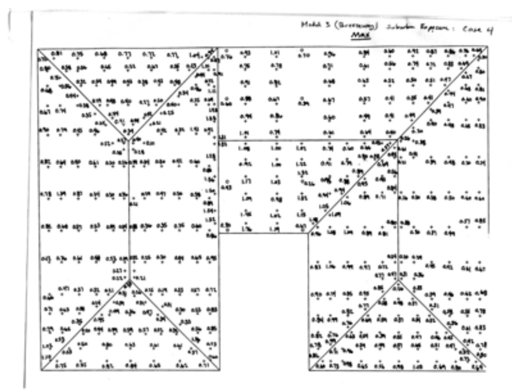
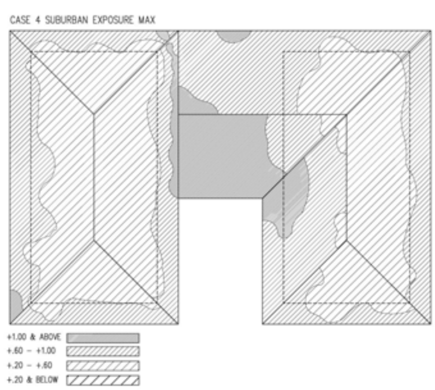


Figure 38a: Pressure Plan



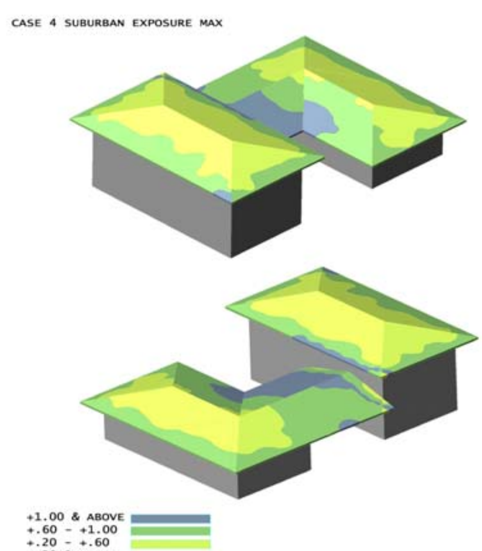


Figure 38b and 38c: Roof Pressure Map

House Model Three - Positive Pressure Maps Conclusions

The zero-lot-line map continues to be the anomaly of the tests. It has to smallest area of high positive pressure contour 1. It has the most complex positive pressure contours. Whereas the contours in the four other maps tend to have clear distinct pressure areas, this map has contours slipping into one another creating erratic patches. In addition, while the other maps all have a distinct high-pressure area above the breezeway on the valley side; this map does not.

As stated before, the remaining positive pressure maps: the Coral Gables map, the cul-de-sac map, the open county map and the open suburban map all exhibit similar pressure contour dispositions with a distinct high pressure area above the breezeway. It seems the three-sided courtyard in front of the breezeway is concentrating the wind through the breezeway causing high pressure on the roof above. The leeward roof tends to have lower pressures with its edge catching some high pressures. The breezeway has caused the one-story section of this house to exhibit greater positive pressure area than the more exposed two-story section. Here, plan configuration not building height has been the more important factor in effecting wind forces on the roof.

Overall Conclusions

Negative Pressure Maps

For all three houses tested, the zero-lot-line neighborhood context significantly lowered uplift roof pressures. For house one and house two, the two-story context rose above to create a wind shelter protecting the lower roofs. The zero-lot-line house was situated amongst a context that extruded its form preventing the wind a chance to create high suction pressures at its edge.

The Coral Gables neighborhood also helped reduce extreme uplift pressures. The one-story house and the breezeway house were both a scale that fit into this context. As a result, they seemed to be protected. The surrounding houses produced an irregular context, which broke up the wind flow. The larger zero-lot-line house did not benefit from this lower context. Only when trees were introduced did the uplift pressures for this house go down.

The cul-de-sac neighborhood consistently performed as the open country and open suburban contexts did. The houses of this context were so far apart from one another that wind forces behaved as if they were not there. Only the breezeway house depicted a slight reduction in uplift pressures. In the case of the zero-lot-line house, this context actually increased uplift pressures.

Context has played a significant role in reducing uplift pressures. The houses tested here were protected from high uplift pressures while situated in dense built up areas are dense vegetation. Left in the open, these houses were exposed to high uplift pressures.

Positive Pressure Maps

When compared to the open country test, only the cul-de-sac neighborhood produced consistent results. The Coral Gables and zero-lot-line neighborhoods had mixed results for each of the three houses.

All the one-story portions of the three houses in the cul-de-sac neighborhood had an overall increase of positive pressure contours. The second-story roofs of the breezeway and zero-line-line house maps had both isolated positive and negative pressure variations but no significant variation from the open country test.

The zero-lot-line neighborhood increased positive roof pressures for the one-story house, the one-story portion of the zero-lot-line house and the upper portion of the breezeway house while it lowered positive pressures for the second-story portion of the zero-lot-line house and the one-story portion of the breezeway house.

The Coral Gables context also produced mixed results: it increased positive pressures for the one-story house and the zero-lot-line house while it maintained similar positive pressures for the breezeway house. The Coral Gables context with trees lowered positive pressures for the second-story portion of the zero-lot-line house and increased positive pressures for the one-story portion.

It seems the three neighborhood contexts generally increased the positive one-story roof pressures (except for the breezeway condition) while a there was some small decreases of the second-story positive roof pressures.

Footnotes

1. Florida Building Code,
   Copyright, The State of Florida, 2001
   First Printing, April 2001

2. Minimum Design Loads for Buildings and Other Structures
   Document Number: ASCE 7-02
   American Society of Civil Engineers
   Reston, Virginia 20191-4400
   01-Dec-2002
   ISBN: 0784406243

3. Zoning, Metropolitan Dade County,
   Municipal Code Corporation
   Tallahassee, Florida 1992, Updated May 25, 1995

3.1.b ROLE OF VEGETATION AS AN IMPACT MODIFIER IN NEIGHBORHOOD DESIGN

Introduction

Architectural design features play as important a role as structural design criteria in modifying the impact of hurricanes on housing. Other elements such as neighborhood layout and landscaping also play a role in modifying the impact of hurricanes on a site or neighborhood specific basis. Such impact modification may be positive or negative, meaning that in some cases the specific feature may contribute to increased damage, while in other cases the design or external feature may reduce the potential for damage from hurricane impact.

Understanding the role design components could contribute is important to the development of knowledge for architects, city planners, developers and home builders, as well as public officials responsible for building design and construction.

The team examined the role of vegetation as an impact modifier for individual dwelling within a neighborhood. The team also researched the effectiveness of various tree and shrub species as impact modifiers in Florida.

Principles of Wind Resistance

Trees develop natural structural responses to wind. “Wind loading is a straight wind from one direction applied evenly over the stem, branches and tree leaves” (Coder, 2001). Under normal weather conditions, trees sway in the wind. The movements caused by alternate loads and releases causes changes in stem material. But, no tree is wind-proof and given enough velocity, any tree will fall or break.

Trees tend to develop extra strength on the windward side. “In conifers, like pine, extra strength is built up on the side of the tree opposite the wind. If the winds are not strong enough to blow the tree over, the tree will develop a trait known as *wind firmness* over several growing seasons… Trees growing under a constant strong north wind are easily damaged by a strong east wind. Fortunately, most open-growth trees develop good wind firmness in all directions over the years. Wind firmness develops over time in response to wind” (Coder, 2001).

Wind resistance depends on the interaction of five factors: strength of the wood; shape and size of the crown; extent and depth of the root system; previous moisture conditions; and shape of the bole. The most wind-resistant form for a tree is one with a well-tapered central leader, a well-spaced framework of branches around and up and down the trunk, and a low center of gravity. The most wind resistant trees are typically compact, slow growing, with major tap roots and well-developed secondary roots.

Native plants have a much better chance of survival in the event a tropical storm or hurricane hits the Gulf Coast. Non-native trees can, and do, survive hurricanes if they develop extensive roots and have adequate foliage density. Natives still offer the best defense against storm damage

Trees growing in sandy soils are more deeply rooted than trees growing in soils with an inhibiting clay layer or a high water table. Although rooting habits vary according to the soil profile, each species has a characteristic pattern.

Strong root growth is essential for tree stability and good health. Past hurricanes have taught us that large growing trees planted too close to curbs, sidewalks or buildings blow over easily. For instance, experts recommend that parking lot islands should be at least 400 square feet in order to support adequate growth for one medium or large maturing tree such as live oak. Recent research and natural disasters have demonstrated that tree roots need much larger soil spaces for strong, stable growth than previously thought.

Adequate soil depth, lack of soil compaction, a deep water table, and adequate rooting space improve root system development and anchorage that contributes to wind firmness.

Observations of native tree hammocks in Miami-Dade County suggest that a large number of trees close together may be an effective storm protection for structures, but no definitive testing of this theory has been carried out. In rural areas, choosing forested or clump settings are better than stand alone trees because the grouped trees reinforced each other.

Also, maintaining healthy trees is critical to reducing damage in hurricanes. Black olive, live oak, and gumbo limbo trees that were pruned survived the hurricane better than the unpruned trees did. Hurricane Andrew study data showed that pruning can improve wind resistance and reduce tree failure. However, pruning does not include the practice of topping, which misshapes and destroys branching structure, nor does it include excessive crown thinning.

“In August 1992 when Andrew came ashore, landscape experts noticed that Louisiana weathered the storm much better than Florida… As development increased in urban areas of Florida during the 1970s, native plants were removed and, in some cases replaced by exotic non-native plants. Consequently the remaining natural landscape became dominated by single trunk pine trees, which; being weak wooded, snap in high winds. Unlike Florida’s urban areas, a lush veil of native vegetation protects Louisiana’s cities. Magnolias, live oaks, cypress trees act as natural windbreaks” (Abbey, 1994).

Several authors noted that trees that readily defoliated survived the hurricane with less overturning. Particularly useful are small, fine textured leaves, particularly deciduous leaves.

A. Principles of wind vulnerability

According to Coder (2001), there are several main types of hurricane related damage to trees: blow-over, stem failure, crown twist, root failure, branch failure. Each type is the result of a complex and interactive mix of tree problems and climate.

> With blow-over, the tree is physically pushed over by high winds. Little biological adjustment is available for a tree (or for people) to make to hurricanes, down-drafts or tornado winds. The wind force on the aerial tree portions is too great for the wood structure. Past tree abuse, poor maintenance, pest problems (like fusiform cankers on pine or root rots on hardwoods) predispose the tree to storm damage by weakening the wood architecture.
>
> Damaged areas can quickly fail under a constant wind loading and release. Pest damage, weak wood around old wounds, new wounds and failure of the tree to adjust to wind conditions can lead to stem failure under heavy wind loading and release. For trees with heavy crowns, abrupt wind gusts and calm periods can lead to stem breakage from release. As the wind load is quickly released, the tree moves back into an upright position. If the mass of the crown moves too quickly when released, the inertia of the moving crown may move too far in the opposite direction leading to stem damage and breakage”.
>
> More wind loading on one side of the crown than on another produces a twist (torque) on major branches and the main stem. Over time, the twisting effect can be biologically adjusted from within the new wood. Stem twisting will

magnify weaknesses around old injuries and the stem will split or branches collapse.

There are two types of tree roots: fine, absorbing roots and woody, structural roots. As their names imply, absorbing roots have a massive surface area but are weak. Structural roots are woody, have a relatively small surface area, but are strong. Both types provide anchorage for a tree. The primary roots growing from the bottom of the stem (root collar) play dominant roles in holding the tree upright while conducting water, essential elements and nutrients. If roots are constrained, diseased or damaged by construction or -- as the top of the tree becomes larger -- greater stress is put on the roots. Pulled or snapped roots cause trees to fall or lean.

Branch failure each year is caused by a small layer of stem wood called the *branch collar*. The branch collar surrounds the branch base. The woody material from the branch enters the stem and turns downward. This structural arrangement allows the branch to be flexible and disposable. The stem can shut off the branch when the branch becomes a biological liability to the tree (Coder, 2001).

Victim trees are typically weighed down by dense canopies and possess high centers of gravity. They are generally fast growing, weak-wooded and shallow rooted (Abbey, 1994).

When trees fell in Hurricanes Erin and Opal, they were either uprooted or broken at the trunk. Uprooting was the most common type of failure for slash and sand pines -- while longleaf pine exhibited both kinds of damage-- and southern red cedar most often broke off at the main stem (Duryea, 1997).

One commonly made mistake in tree selection is to plant fast-growing trees. There are two built-in factors that exist in most fast-growing trees. First, most fast-growing trees are not built to withstand storms. They are weak-wooded and subject to splitting, cracking and breaking during a storm. Second, most fast-growing species are short-lived. For example, a short-lived tree such as a silver maple may live for a few decades as compared to a more durable tree such as a live oak, which can live for a couple of hundred years (Williams, 1999).

Another class of damage occurs when the whole tree blows over rather than breaking up. The soil in which the trees are growing may have a major influence on how shallow-rooted a tree is, but there are certain species that almost never make deep roots, and these are always likely to blow over. On poorly drained soils, such as marl, where the water table periodically comes close to the soil surface, most trees that would otherwise form deep roots will be shallow-rooted and much more easily blown over than they would be on well drained soils. In Dade County, where limestone can be a problem, dynamiting before planting is very helpful in opening cracks through which the roots can travel. Once established, trees planted in this way are extremely resistant to blowing over. Unfortunately, dynamiting is not allowed in a number of areas (Burch, 2003).

Pines have most often been placed relatively low on hurricane-resistance lists due to their propensity for stem breakage. Hurricane damage to pine trees can also initiate outbreaks of pests such as bark beetles, ambrosia beetles, sawyers, and blue stain fungi that preferentially attack stem-damaged pines. After Hurricane Andrew in 1992, many individual pines did not show immediate damage but died during the following year.

Even though high percentages of slash and longleaf pines were standing after Hurricanes Erin and Opal, their ability to survive hurricane level stresses may be less than other species. 21% and 8% of the fallen trees damaged property in Erin and Opal; respectively. (Of all the trees surveyed, just 2% and 1% damaged property.) Homes accounted for 67% and 29% of the damage in Hurricane Erin and Opal; the rest was damage to minor structures such as signs, fences and sidewalks.

In the study made after Hurricane Andrew, only 18% of the fallen trees damaged property and of the total trees in the survey only 7% damaged property. It is common after a hurricane for urban citizens to decide that trees are a problem and are undesirable due to their damage potential. In this study we found only 1 to 2 % of the trees studied caused damage to property. While damage is undesirable at any level, impact on property can be balanced against the many other benefits of urban trees including energy conservation, reduction of storm water runoff, wildlife habitat and beauty (Duryea, 1997).

B. Windbreaks

There are four principles of wind control – obstructing, filtering, deflecting, and guiding. The best wind resistant trees are compact and have major tap roots. Trees with a tapered trunk have a low center of gravity and are more stable. The best example of such a tree is the Live oak. Live oaks force surface winds up and over buildings while slowing and filtering wind gusts. This protects nearby structures from extensive wind damage. Older live oaks are even more wind resistant because they are stronger and possess open finback canopies and long limbs which extend toward the ground balancing the treaty. During Andrew live oaks forced surface wind up and over buildings in urban areas of Louisiana law slowly and filtering windows (Abbey, 1994).

Barriers provided by hedges are excellent in preventing wall and window damage from high winds and airborne debris. Dense foliage such as hedgerows can cut wind velocity by as much as 60 percent in some cases. Protector plant groves of tightly planted trees intercept flying debris (Abbey, 1993).

In the article “Protecting Mobile Homes”, Virginia Peart writes:

> By Florida law mobile homes must be anchored to withstand hurricane-force winds. Installation of mobile homes should be done by a professional. Additional planning to protect from high winds includes… [establishing] a windbreak if possible. Natural barriers such as trees provide excellent windbreaks. Two or more rows of trees are more effective than a single row. Four rows are best. Trees which are at least 30 feet high are most effective (Peart, 1994).

C. A summary of the wind resistance of Florida plants

The team compiled a matrix of the most and least wind resistant Florida trees, shrubs, palms. The lists are based on analyses of multiple articles and reports about Florida landscaping. Several patterns emerge in the matrices:

- There is broad consensus that the live oak and sabal palm are Florida’s most wind resistant trees.
- There is little relationship between the wind resistance of a tree, and the trees ability to serve as effective windbreaks. Live oaks, for example are excellent windbreaks but sabal palms are not. Slash and longleaf pines are excellent windbreaks, but are not wind resistant.
- There is a lack of research and consensus on some of the best and the worst. Red cedar, elms, sweetgum, hickory, mango, pecan, and pines all appear on some authors’ “most wind resistant” lists, and others’ “least wind resistant”.
- Context is important. A cluster of pines may serve as an outstanding windbreak, with superb wind resistant qualities. A pine standing by itself is a victim tree.

TABLE 1. MOST WIND RESISTANT TREES

Tree	Location in Florida	Also on <u>least</u> resistant list	Comments	Source
Ash , Green	Panhandle			Cook
Beech	Panhandle			USDA
Birch, River	North Florida			Abbey
Olive, Black	South Florida		Good windbreak	Black
Box leaf stopper	South Florida and Keys			Duryea, et. al.
Cedar, Red	Throughout state	yes	Good windbreak	Orlando
Cottonwood, Eastern	Northern half of state		Good windbreak	Black
Myrtle, Crape	Throughout state			Abbey
Cypress, Pond	Throughout state, except keys		weak wood, but its crown is so sparse and its foliage so limber that it is also extremely windfirm	Abbey
Cypress, Bald	Throughout state, except keys		weak wood, but its crown is so sparse and its foliage so limber that it is also extremely windfirm	Abbey, Cook
Dogwood	Northern half of state			Duryea
Elm, American	Northern half of state	yes		Abbey
Elm, Winged	Northern half of state	yes		Abbey
Geiger tree	Keys			Duryea, Burch
Gum, Black	Northern two-thirds of state			USDA, Abbey
Gum, Sweet	Northern half of state	yes		Abbey, USDA
Gumbo limbo	Southern half of state			Duryea, et. al.
Hackberry	Throughout state, except keys			Abbey
Hawthorne, Indian	North Florida			McDavid
Hickory	Central Florida	yes		Cook
Holly, American	Northern half of state			Abbey
Holly, Dahoon	Throughout state, except keys			Abbey
Holly, Savannah				
Holly, yaupon	North Florida			McDavid
Hop Hornbeam, American	Northern half of state			Abbey
Iron Wood	Northern half of state			Abbey
Locust, Black (legume)	Panhandle			Abbey
Magnolia, Southern	Northern half of state			Duryea, Abbey, USDA
Magnolia, Sweet Bay	Throughout state, except keys			Duryea, Abbey, USDA
Mahogany	South Florida and Keys			Duryea, Burch

Table 1. (continued)				
Tree	**Location in Florida**	**Also on <u>least</u> Resistant list**	**Comments**	**Source**
Mango		yes		Burch
Maple, Sugar	North Florida			USDA
Mimusops				Burch
Oak, Nuttall	North Florida			Abbey
Oak, Bluff	Panhandle, north Florida			Cook
Oak, Cherrybark	Panhandle			Abbey
Oak, Cow	North Florida			Abbey
Oak, Live	Throughout state		Deep root systems with buttressed trunks (low center of gravity). The wood of live oak is exceedingly strong and resilient. The crown is usually widespread, but this does not seem to negate its strong points	Duryea, Abbey, USDA, Cook, Burch
Oak, Shumard	North Florida			Abbey
Oak, Southern	North Florida			USDA
Oak, White	North Florida			USDA
Oak, Willow	Panhandle			Abbey
Osage Orange	Northern half of state			Abbey
Palm, Mexican Fan	Throughout state		They will tend to bend and flex with the wind.	Abbey
Palm, Alexander	Throughout state		They will tend to bend and flex with the wind.	Duryea, et. al.
Palm, Areca	Throughout state		They will tend to bend and flex with the wind.	Duryea, et. al.
Palm, Cabada	Throughout state		They will tend to bend and flex with the wind.	Duryea, et. al.
Palm, Sabal (also known as cabbage palm)	Throughout state		In one hurricane, The only sabal palm recorded as fallen was knocked over by another fallen tree. They will tend to bend and flex with the wind.	Abbey, Duryea, Cook
Palm, Windmill	Throughout state		They will tend to bend and flex with the wind.	Abbey
Palmetto, saw	Throughout state			McDavid
Pecan	North Florida	yes		Cook
Plum, Pigeon	South Florida and Keys			Duryea
Pine, Longleaf	Northern half of state	yes	Good windbreak	Black
Pine, Slash	Throughout state	yes	Good windbreak	Black
Sycamore	Panhandle			Abbey, USDA
Tamarind	South Florida			Duryea, Burch
Tulip Tree	Northern half of state			Abbey, USDA

TABLE 2. LEAST WIND RESISTANT TREES

Tree	**Location in Florida**	**Also on <u>most</u> resistant lists?**	**Comments**	**Source**
Acacia, Earleaf			Brittle species	Burch
African tulip tree			Brittle species	Burch
Bischofia			Brittle species	Burch
Box Edlers	North Florida		Brittle species	Abbey, Andresen
Cedars, Red	Throughout state	yes	Often broke off at main stem	Abbey
Ear tree			Brittle species	Burch
Elms	Northern half of state	yes	Brittle species	Andresen
Eucalyptus			Brittle species	Burch
Fruit trees: navel orange, mango, avocado, and grapefruit	Southern half of state	yes	Many severely damaged in Andrew	Duryea, et. al., Burch
Gum, Sweet	Northern half of state	yes		Cook
Hickories	Central Florida	yes		Abbey
Laurel, cherry	Throughout state			Duryea, Cook
Laurelberry, Carolina				Duryea
Maple, Red	Throughout state			Duryea
Maples, Silver	Panhandle		Brittle species	Abbey, Andresen
Oak, Laurel	Throughout state			Duryea, Cook
Oak, Silk			Brittle species	Burch
Oak, Southern Red				Duryea
Oak, Turkey				Duryea
Oak, Water	Throughout state		Trees that had short, shallow roots. It is a classic example of fast-growing, weak wooded trees that have a shallow-root system	Abbey,Cook
Oaks, Red	North Florida			Abbey
Pecans	North Florida	yes	It is weighed down by a dense canopy and possesses a high center of gravity. They are generally fast growing , weak-wooded and shallow rooted	Abbey, Duryea
Pine, Norfolk Island			Shallow root	Burch
Pine, Australian			Shallow root	Burch
Pine, Sand	Northern half of state		Its shallow root system appears to make it extremely vulnerable to wind.	Duryea
Pine, Longleaf	Northern half of state	yes	The taller the tree, the greater is its chance of breaking, especially if the bole has little taper	USDA, Abbey, Duryea
Pine, Slash	Throughout state	yes	The taller the tree, the greater is its chance of breaking, especially if the bole has little taper	USDA, Abbey
Poplar			Brittle species	Andresen

Table 2. (continued)				
Tree	**Location in Florida**	**Also on <u>most</u> resistant lists?**	**Comments**	**Source**
Sea hibiscus			Brittle species	Burch
Seaside mahoe			Shallow root	Burch
Sugar berry				Cook
Tallow, Chinese				Duryea
Willows			Brittle species	Andresen
Woman's tongue			Shallow root	Burch

D. References: hurricanes and landscape

Researchers developed a partially annotated bibliography on significant books, articles, web sites, reports, brochures that deal with wind and trees. The bibliography is organized in the following categories: Management, Maintenance and Restoration; Mitigation, Landscape Design; Urban Forests; Morphology; Post-Hurricane Assessments; and Bibliographies.

Cities in hurricane prone urban areas have greatly expanded in the past fifty years and along with this expansion is an increase in the area of urban forest. In Florida alone, approximately 410 acres of natural forest is converted to urban land use every day and population is expected to increase to over 20 million residents by 2010. As urban land area expands, it is becoming increasingly important to understand the ecology of the urban forest and the potential effects of hurricanes on both the structure of the forest and patterns of property damage. While a fairly large body of research exists on the effects of hurricanes on natural forests and ecosystems such as the patterns of wind damage (Laurance 1998), recovery (Basnet 1993, Hull 1996), mortality (Belingham et al 1992), and even replanting (Straka 1995), very few studies have investigated the effects of hurricanes on urban forests.

a. Management, Maintenance and Restoration

Basnet, K. 1993. “Recovery of a Tropical Rain Forest After Hurricane Damage.” *Vegetatio* 109: 1-4.

Coder, Kim. February 2001. *Storm Damaged Trees: Prevention and Treatment.* Cooperative Extension Service. The University of Georgia College of Agricultural and Environmental Sciences.

Thousands of shade and street trees are lost every year to wind, ice and lightning. Estimates of property value loss in Georgia from this type of tree damage can exceed $10 million annually. This value does not include future liability problems. Georgia has 50 to 70 thunderstorm days each year. Each storm can cause extensive damage to trees along its path. Historic, rare and specimen trees, especially when landscapes are designed around them, are valuable. These trees can become major aesthetic, financial and social losses in storms. This publication summarizes information to help you understand and prevent storm damage to trees. It also lists resistant species of trees to plant, types of tree storm damage and treatments, and lightning protection systems information.

Everham, E.M., and N.V.L. Brokaw. 1996. “Forest Damage and Recovery from Catastrophic Wind.” *Botanical Review* 62: 113-185.

The literature on the effects of catastrophic wind disturbance (windstorms, gales, cyclones, hurricanes, tornadoes) on forest vegetation is reviewed to examine factors controlling the severity of damage and the dynamics of recovery.

Haymond, J.L., D.D. Hook, and W.R. Harms. 1996. “Hurricane Hugo: South Carolina Forest Land Research and Management Related to the Storm.” *General Technical Report (SRS-GTR-5), pp.540.* USDA Forest Service. Southern Research Station.

Hurricane Hugo was probably one of the most destructive hurricanes to assault the forests of the Eastern United States in recorded history. Four and one-half million acres were damaged in North Carolina and South Carolina, an estimated 21.4 billion board feet of timber were destroyed or damaged, and several federally listed endangered species. In addition to the reports in this compilation, more reports can be expected as on-going and new studies of forest damage, restoration, and rehabilitation are completed.

USDA. 1982. “How to Evaluate and Manage Storm-Damaged Forest Areas.” *Forestry Report (SA-FR 20).* USDA Forest Service.

“Modeling Hurricane Effects on Mangrove Ecosystems.” June 1997. *Agriculture Forest Service Comprehensive Regional Resource Assessments and Multipurpose Uses of Forest Inventory and Analysis Data, 1976 to 2001: A Review.* USGS.

> Mangrove species and forests are susceptible to catastrophic disturbance by hurricanes such as Andrew that cause significant changes in forest structure and function. These functional relationships of hurricane impacts on mangrove species and systems have been incorporated into a landscape simulation model of south Florida mangroves.

Siegendorf, L. "Hurricane Tree Care." *Journal of Arboriculture* 10: 217.

Straka, T.J., A.P. Marsinko, J.L. Baumann, and R.G. Haight. 1995. "Site Preparation and Tree Planting Costs on Hurricane-Damaged Lands in South Carolina." *Southern Journal of Applied Forestry* 19: 131-138.

Walker, L.R. 1995. "Timing of Post Hurricane Tree Mortality in Puerto Rico." *Journal of Tropical Ecology* 11: 315-320.

b. Mitigation

Burch, Derek. September 1985 / October 2003. *How to Minimize Wind Damage in the South Florida*. Florida Cooperative Extension Service. Institute of Food and Agricultural Sciences. University of Florida.

> When an area has been free of hurricane-strength winds for a number of years, there is a possibility of severe damage to trees and to the structures near them when a storm finally hits. Trees and shrubs, even those native to an area, can grow too massive or unbalanced to be able to stand windstorms, and it is worth learning how to prune and shape trees in order to minimize the risks of damage.

Cook, Gary. May 1993. "Hurricane Preparedness and Wind Resistant Homes." *Energy Efficiency and Environmental News*. Florida Energy Extension Service.

McDavid, Chance, "Weather the Storm with Native Plants," *Coast Gardener,* July 21, 2001.

Hazard Tree Management Program - A Hurricane Mitigation Strategy for Alachua County. Undated. Alachua County.

> The overall objective of this project is to design model mitigation techniques to be incorporated into comprehensive landscape management programs that

will reduce the destructive impacts hurricanes shall have on public and private property.

"Reducing Tree Damage in Future Storms." December 2002. *National Arbor Day Foundation Report*.

The National Arbor Day Foundation offers these suggestions for pruning a tree that will promote the growth of strong branches.

Straka, T.J., A.P. Marsinko, J.L. Baumann, and R.G. Haight. 1995. "Site Preparation and Tree Planting Costs on Hurricane-Damaged Lands in South Carolina." *Southern Journal of Applied Forestry* 19, 131-138.

Williams, Larry, "Evaluate Hurricane Resistance of Your Trees," *NW Florida Daily News*, June 03, 1999.

c. Landscape Design

Abbey, D.G. 1994. *Hurricane Resistant Landscapes.* Louisiana Department of Agriculture and Forestry.

Abbey, D. Gail, and Jean Coco. May/June 1998. "Hurricane-Resistant Landscapes." *City Trees, The Journal of The Society of Municipal Arborists* 34 (3).

What to do, to prepare the landscape for a Hurricane? No hurricane landscape codes exist, and further there is practically no research data available to help landscape architects, architects and engineers design hurricane resistant landscapes. To try to provide answers to these questions and to generate some useful information about vagabond tropical storms, a research project funded by the Louisiana Department of Agriculture and Forestry was undertaken by the School of Landscape Architecture following the roaring visit Hurricane Andrew.

Black, R.J. September 1985 / June 1997. *Native Florida Plants for Home Landscapes.* Florida Cooperative Extension Service. Institute of Food and Agricultural Sciences. University of Florida.

The state has nearly half of the species of trees available in North America north of Mexico. So many of Florida's native plants are useful that the tables included here list only those with the greatest potential landscape use.

Barry, P.J., R.L. Anderson, and K.M. Swain. 1982. “How to Evaluate and Manage Storm-Damaged Forest Areas.” *Forestry Report (SA-FR 20).* USDA Forest Service, Southeastern Area.

This guide presents methods for managing storm-damaged trees to reduce growth loss, product degrade, and mortality. In the process, other factors such as threatened and endangered species must be considered.

“New Development Should Be Avoided in Tsunami Hazard Areas.” March 2001. *Designing for Tsunamis: Background Papers.* The National Tsunami Hazard Mitigation Program.

Land use and site planning should emphasize keeping new development out of hazard areas. Hazard areas should be kept as open space and may incorporate physical barriers such as landscape, berms, and engineered walls to slow and steer run-up.

Peart, Virginia. November 1992. *Protecting Mobile Homes*. Institute of Food and Agricultural Sciences. University of Florida.

d. Urban Forests

Abbey, Buck. *Hurricane Resistant Urban Forests*. LSU Hurricane Center. Louisiana State University.

Andresen, J.W., T. Bartlett, and L.L. Burban. 1993. “Protect your Urban Forest from Wind Damage: Operation Tornado ReLeaf.” *Arboricultural Journal* 17: 277-286.

Testing the Effectiveness of a Local Ordinance. Undated. http://americanforests.org/

The energy conserving benefits of trees in the Miami area were made dramatically apparent in the wake of Hurricane Andrew. An Urban Ecosystem Analysis showed that the hurricane, combined with years of increasing urban sprawl, left the community with only a 10% tree canopy, still generating significant energy savings benefits of $5.3 million per year to homeowners. With so much to be gained though a modest canopy increase, the new Dade

County Landscape Ordinance required all new development to strategically plant trees for energy conservation. The community was able to prove the positive impact of the ordinance by modeling tree plantings using CITYgreen.

e. Morphology of Trees and Forests

Coutts, M.P., and J. Grace. 1995. *Wind and Trees*. Cambridge University Press.

"Describes the physiological responses to wind in leaves, stems, and root systems, and ecological considerations of wind throw, detailing management techniques for forests in windy climates and explaining the use of models for predicting wind damage" (Book News).

Ennos, A.R. 1997. "Wind as an Ecological Factor." *Trends in Ecology and Evolution* 12: 108-111.

Laurance, William F. 1998. "Rain Forest Fragmentation and the Dynamics of Amazonian Tree Communities." *Ecology*.

Nelson, Gil. 1994. "The Trees of Florida - A Reference and Field Guide." *Pineapple Press, Florida.*

A guide to Florida's tree species, organized by the 77 families which include trees in the state. Gives scientific and common names, and information on medicinal, food, and ornamental uses for some 350 trees and shrubs (Book News).

Nicklas K.J. 2002. "Wind, Size and Tree Safety." *Journal of Arboriculture* 28 (2): 84-93.

Riatheng, Nelda, and James R. Clark. 1994. *Photographic Guide to the Evaluation of Hazard Trees in Urban Areas.* HortScience Inc.

This book is designed to assist managers in evaluating the hazard potential of trees. By providing a systematic rating approach, evaluations allow managers to identify hazard situations, rank their relative severity, and create a priority for work.

Smiley, E. Thomas, and Kim D. Coder. 2002. *Tree Structure and Mechanics Conference Proceedings: How Trees Stand Up and Fall Down.* International Society of Arboriculture.

The conference expanded its goal of expanding discussion of tree biomechanics among researchers, educators, and practitioners.

Straka, T.J., A.P. Marsinko, J.L. Baumann, and R.G. Haight. 1995. “Site Preparation and Tree Planting Costs on Hurricane-Damaged Lands in South Carolina”. *Southern Journal of Applied Forestry* 19: 131-138.

Vogel, S. 1996. “Blowing in the Wind: Storm-Resisting Features of the Design of Trees.” *Journal-of- Arboriculture* 22 (2): 92-98.

Many of the features of trees represent arrangements that minimize the chance that they will uproot when exposed to high winds. At least four schemes, singly or in combination, keep the bases of trees from rotating in the face of the turning moment imposed by the drag of their leaves. Trunks and petioles are relatively more resistant to bending than to twisting, giving good support but permitting drag-reducing reconfiguration in high winds. Leaves curl and cluster in a variety of ways, all of which greatly reduce the drag they incur relative to the values for ordinary thin and flexible objects such as flags.

f. Post-Hurricane Assessments

Bellingham, P.J., V. Kapos, N. Varty, J.R. Healey, E.V.J. Tanner, D.L. Kelly, J.W. Dalling, L.S. Burns, D. Lee, and G. Sidrak. 1992. “Hurricanes Need Not Cause High Mortality: The Effects of Hurricane Gilbert on Forests in Jamaica.” *Journal of Tropical Ecology* 8: 217-223.

Boose, E.R., D.R. Foster, and M. Fluet. 1994. “Hurricane Impacts to Tropical and Temperate Forest Landscapes.” *Ecological Monographs* 64: 369-400.

Conner, W.H., and A.D. Laderman. 1998. “Impact of Hurricanes on Forests of the Atlantic and Gulf Coasts, USA.” *Coastally Restricted Forests*, 271-277. New York, USA: Oxford University Press.

Crane, J.H., A.J. Dorey, R.C. Ploetz, and C.W. Weekley, Jr. 1995. “Post, Hurricane Andrew Effects on Young Carambola Trees.” *107th Annual Meeting of the Florida State Horticultural Society* 107: 338-339.

Doyle, Thomas W., Thomas C. Michot, Fred Roetker, Jason Sullivan, Marcus Melder, Benjamin Handley, and Jeff Balmat. 2002. ”Hurricane Mitch: Landscape Analysis of Damaged Forest Resources of the Bay Islands and Caribbean Coast of Honduras.” *U.S. Geological Survey*.

> In this study, researchers conducted a video overflight of coastal forests of the Bay Islands and mainland coast of northern Honduras 14 months after impact by Hurricane Mitch (1998). Coastal areas were identified where damage was evident and described relative to damage extent to forest cover, windfall orientation, and height of downed trees. The variability and spatial extent of impact on coastal forest resources is related to reconstructed wind profiles based on model simulations of Mitch’s path, strength, and circulation during landfall.

Duryea, Mary L. May 1997. *Wind and Trees: Surveys of Tree Damage in the Florida Panhandle after Hurricanes Erin and Opal.* Florida Cooperative Extension Service. Institute of Food and Agricultural Sciences. University of Florida.

> Hurricanes Erin and Opal swept across the Florida Panhandle in 1995 bringing with them sustained winds of 85 and 125 mph. In two surveys immediately following the hurricanes, 25 neighborhoods were inventoried for tree damage. This circular summarizes the results of our surveys and ranks the wind resistance of the North Florida tree species in these communities. Hurricane-susceptible communities should consider wind resistance as one of their criteria in tree species selection.

Duryea, Mary L., George M. Blakeslee, William G. Hubbard, and Ricardo A. Vasquez. January 1996. “Wind and Trees: A Survey of Homeowners after Hurricane Andrew.” *Journal of Arboriculture* 22 (1).

> The destructive winds of Hurricane Andrew dramatically changed the urban forest in Dade County, Florida, on August 24, 1992. Overnight, the tree canopy was replaced by a landscape of unbroken, uprooted, defoliated, and severely damaged trees. To assist communities in reforestation efforts,

scientists at the University of Florida conducted a homeowner survey to determine how different tree species responded to strong winds.

Daniels, Richard F. *GIS and Inventory Technologies Pay Off in Hurricane Hugo Recovery*. Summerville, SC: Westvaco Corporation.

Faust, T.D., M.M. Fuller, R.H. McAlister, and S.J. Zarnoch. 1994. "Assessing Internal Hurricane Damage to Standing Pine Poletimber." *Wood and Fiber Science* 26: 536-545.

Francis, J.K., and A.J.R. Gillespie.1993. "Relating Gust Speed to Tree Damage in Hurricane Hugo." *Journal of Arboriculture* 19: 368-373.

Gresham, C.A., T.M. Williams, and D.J. Lipscomb. 1991. "Hurricane Hugo Wind Damage to Southeastern U.S. Coastal Forest Tree Species." *Biotropica* 23: 420-426.

Jacobs, D.M., and S. Eggen-McIntosh. June 21-24, 1993. "Airborne Videography and GPS for Assessment of Forest Damage in Southern Louisiana from Hurricane Andrew." *Proceedings of the ILJFRO Conference on Inventory and Management Techniques in the Context of Catastrophic Events.* University Park, PA.

One week after Hurricane Andrew made landfall in Louisiana in August 1992, an airborne videography system, with a global positioning system (GPS) receiver, was used to assess timberland damage across a 1.7 million-ha (4.2 million-acre) study area. Ground observations were made to identify different intensities of timber damage and then cross-referenced with the aerial video using GPS coordinates.

Ham, D.L., and R.C. Rowe. 1990. "Tree Devastation by Hurricane Hugo. *Arboriculture* 16: ix-x.

Hull, D.L. 1996. "Facilitation of Hurricane Recovery in Miami." *Principes* 40: 208-211.

Milner, M. 1990. "Hugo: Diary of a Disaster." *Am. Nurseryman* 171: 45-49.

Ogden, J.C. 1992. "The Impact of Hurricane Andrew on the Ecosystems of South Florida." *Conserv. Biol.* 6: 488-490.

Reilly, A.E. 1998. “Hurricane Hugo: Winds of Change or Not? Forest Dynamics on St. John, US Virgin Islands, 1986-1991.” In F. Dallmeier and J.A. Comiskey, eds., *Forest Biodiversity in North, Central and South America, and the Caribbean: Research and Monitoring*. Man and the Biosphere Series 21, 349-365.

Swain, K.M. 1979. “Minimizing Timber Damage from Hurricanes.” *S. Lumberman* 239: 107-109.

Tanner, E.V.J., V. Kapos, and J.R. Healey. 1991. “Hurricane Effects on Forest Ecosystems in the Caribbean.” *Biotropica* 23: 513-521.

Touliatos, P., and E. Roth. 1971. “Hurricanes and Trees: Ten Lessons from Camille.“ *J. For* 285-289.

Trickel, Rob. September 2003. *North Carolina Forest Damage Appraisal—Hurricane Isabel*. North Carolina Division of Forest Resources.

> To determine the amount of forest damage caused by the storm, a damage appraisal was conducted in the original 26 counties.

Zimmerman, J.K., W.M. Pulliam, D.J. Lodge, V. Quinones-Orfila, N. Fetcher, S. Guzman-Grajales, J.A. Parrotta, C.E. Asbury, L.R Walker, and R.B. Waide. 1995. “Tree Damage and Recovery from Hurricane Hugo in Luquillo Experimental Forest, Puerto Rico.” *Biotropica* 23: 379-385.

> Hurricane Hugo Struck Puerto Rico on 18 September 1989 with maximum sustained winds of over 166 km/hr (Scatena & Larsen 1991) and caused severe defoliation of 56 percent of the trees in study plots at El Verde in the Luquillo Experimental Forest (LEF). Some trees were uprooted (9%) or had trunks that snapped (11%), but overall mortality was low (7%). Damage was patchy on twenty 300 m2 plots with most damage occurring on north-facing sites. Tall trees and trees with large diameters were most likely to be uprooted, but success ional status of trees was not a good predictor of the amount of damage the trees sustained. Recovery patterns varied among species but refoliation was rapid. Widespread sprouting and minimal breakage of large branches will probably lead to the recovery of most trees.

g. Bibliographies

Cullen, S. 2002. “Trees and Wind: A Bibliography for Tree Care Professionals.” *Journal-of-Arboriculture* 28 (1): 41-51.

Coder, Kim. 1999. “Hurricanes, Trees & Forests: A Selected Bibliography.” Report. University of Georgia.

> Hurricanes and trees do not mix well. This publication cites recent publications and journal articles which deal with various aspects of hurricane impacts on trees and forests. This not a comprehensive review but selected to provide a broad view of work and workers in this area. This selected bibliography is provided for educational purposes.

3.2 PERFORMANCE MODIFIERS IN THE MITIGATION OF ROOF DAMAGE

Background

With respect to (b) *Performance Modifiers in the Mitigation of Roof Damage*, above, the IHRC Team prefaced the issue as follows:

> *The performance of roofs under hurricane impacts may be modified or improved by the use of design [criteria] and construction methods or materials that go beyond the minimum prescriptions of the building code. Research, including that conducted by the IHRC research team, has shown the improvement of performance could be significant. When such improvement in performance is achieved at low cost or at a high benefit-cost ratio, one that is acceptable to home-builders or home-buyers, then a strong case can be made in favor of adopting such performance modifiers as standard house design or construction methods.*

Research work conducted during the 2001-2002 and the 2002-2003 HLMP grant periods showed the performance of roof sheathing under the impact of hurricanes could be improved by a factor of up to 130% by replacing the type of fastener used to attach the roof deck to its supporting structure. Applying the above mentioned philosophy and on the basis of past research findings, the IHRC Team decided to submit a proposal to modify the Florida Building Code.

The proposal was submitted to the Florida State Building Code Commission through the established open process in April of 2003. Prior to submitting its proposal, the IHRC Team had shared its findings with key stakeholders such as *The Florida Home Builders Association*, *the Institute for Business and Home Safety* and *the Miami-Dade County Local Mitigation Strategy*, as well as with researchers and building-design and construction professionals from *Florida International University Department of Construction Management* and *College of Engineering*, also from the *Department of Civil Engineering* at *Clemson University* [Clemson, SC].

The proposal addressed specific sections of the Florida Building Code that are applicable to the *High Velocity Hurricane Zone* [HVHZ]. The text of the proposed building code modification together with the answers to questions required by the State Building Code Commission are shown below:

Proposed Modification to the Florida Building Code

Modification #: 856 **<u>Section 553.73, Fla Stat</u>**

Name: Ricardo A. Alvarez
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MARC 360
Florida International University
Miami, FL 33199
E-mail: alvarez@fiu.edu
Phone: [305] 348-1607
Fax:` [305] 348-1605
Code: Florida Building Code
Section #: 2322.2.4, 2322.2.5, 2322.2.5.1, 2322.2.5.2

Text of Modification [additions <u>underlined</u>; deletions ~~stricken~~][1]:

2322.4 Plywood panels shall be nailed to supports with 8d ring shank nails.

2322.2.5 Nail spacing shall be 6 inches (152 mm) on center at panel edges and at intermediate supports. Nail spacing shall be 4 inches (102 mm) on center at gable ends with either 8d ring shank nails or 10d common nails.

2322.2.5.1 Nails shall be hand driven 8d ring shank or power driven 8d ring shank nails of the following minimum dimensions: (a) 0.113 inch (2.9 mm) nominal shank diameter, (b) ring diameter of 0.012 inch (0.3 mm) over shank diameter, (c) 16 to 20 rings per inch, (d) 0.280 inch (7.1 mm) full round head diameter, (e) 2-3/8 inch (60.3 mm) nail length. Nails of a smaller diameter or length may be used only when approved by an Architect or Professional Engineer and only when the spacing is reduced accordingly.

2322.2.5.2 Nails at gable ends shall be hand driven 8d ring shank or power driven 8d ring shank nails of the following minimum dimensions: (a) 0.113 inch (2.9 mm) nominal shank diameter, (b) ring diameter of 0.012 inch (0.3 mm) over shank diameter, (c) 16 to 20 rings per inch, (d) 0.280 inch (7.1 mm) full round head diameter, (e) 2-3/8 inch (60.3 mm) nail length or as an alternative hand driven 10d common nails [(0.148 inch (3.8 mm) diameter by 3 inches (76 mm) long with 0.312 inch (7.9 mm) diameter full round head)] or power driven 10d nails of the same dimensions (0.148 inch diameter by 3 inches long with 0.312 inch diameter full round head). Nails of a smaller

[1] The final version of the text is shown. For the sake of clarity underlined additions and stricken deletions have been omitted.

diameter or length may be used only when approved by an Architect or Professional Engineer and only when the spacing is reduced accordingly.

<u>Fiscal Impact Statement</u> **[Provide documentation of the costs and benefits of the proposed modifications to the code for each of the following entities. Cost data should be accompanied by a list of assumptions and supporting documentation. Explain expected benefits.]:**

A. Impact to local entity relative to enforcement of code:

Impact to local building code enforcement entity will be negligible. The reason for this is that while the type of nail is being changed the nailing schedule remains the same hence there will be no change to the roof inspection process. The entity would need to require samples of the nail or nails being used during the inspection process in order to verify that it or they meet the criteria prescribed by the code. Other than that there is nothing else that the local entity would need to do.

B. Impact to building and property owners relative to cost of compliance with code:

Negligible impact. There could be a very small cost increase in the materials [nails] used to fasten the roof sheathing to the roof structure. This minor increase in the cost of materials would be partially offset by an increase in labor productivity resulting from the smaller diameter of the 8d ring shank nails, when compared to the 8d common nails, which allows more nail to fit in the coil or magazine of the nailing gun, thus requiring fewer stops to reload the nailing gun. The contractor will probably pass any cost increase on to the building and property owners. Based on data from nail suppliers the cost increase may average $0.38 (38 cents) per roofing square (100 square feet of roof). Even if we ignore the improvement in labor productivity, this translates to a total of $7.60 for a house with a 2,000 square foot roof. Regarding the gable ends there could be an actual decrease in cost when the 8d ring shank nails are used instead of the 10d common nails. This reduction will result from the lower cost of the nails and also from the higher productivity in labor derived from the fact that there is no need to change nails when nailing the gable end sheathing.

C. Impact to industry relative to cost of compliance with code:

No adverse impact whatsoever. There is a positive impact due to higher productivity for power driven nailing. There is no additional labor for contractors using nailing guns since the nailing schedule remains the same. In fact there may be a slight reduction in cost as the 8d ring shank nail has a smaller diameter that the currently prescribed 8d common, and more nails can be loaded on the power tool reducing the number of times the roofer needs to stop to reload. There will be a very small increase in the cost of materials [nails].

An informal survey of various nail suppliers shows that 8d common nails can be purchased in coils for an average, in Miami-Dade County, of $25.51 for a box of 3,600 nails or a unit cost of $0.0071/nail. The 8d ring shank nails in coils, also in Miami-Dade County, can be purchased for an average of $55.97 for a box of 6,000 or a unit cost of $0.0093/nail.

A 4'x8' roof panel takes 45 nails under the prescribed nailing schedule. A roof square, 100 square feet, is equal to 3.125 panels and requires 140.6 nails to fasten it to the structure.

Using the unit cost per nail given above the cost of nails to fasten one square of roof sheathing using 8d common nails is $0.99, and $1.30 when using 8d ring shank nails. The cost increase due to the cost of nails is 1.30 – 0.99 or 0.31. If we multiply this by a factor of 1.22 to account for taxes, overhead and profit we obtain 0.31 x 1.22 = 0.378 rounded up to $0.38 per square.

The total cost increase for a house with 2,000 square feet of roof (20 squares) is $0.38 x 20 = $7.60. This additional materials cost could be passed on to the homeowner. This minimal increase will be offset in cases when the 8d ring shank nails is also used at gable ends instead of changing to the 10d common nail.

The same equipment, nail gun, can be used for driving both types of nails therefore there is no additional equipment cost in most cases.

Rationale [Provide an explanation of why you would like this Proposed Modification to the Florida Building Code.]:

Implementing this proposed modification will significantly improve the performance of roofs under the impact of hurricane winds. Reducing the potential for damage to roofs is essential to preserving the integrity of the building envelope. Obtaining a significant improvement in performance and doing so at basically minimal to negligible cost increase, provides a rather generous benefit-cost ratio.

Building Code provisions, such as those adopted by the 2001 Florida Building Code, fall into two categories: (1) Performance criteria used to establish minimum design loads, and (2) Prescriptive requirement that, in the case of roof sheathing, establish minimum lumber and panel thickness and the type and spacing of fasteners.
Based on the wind load provisions of ASCE 7-98 the design wind speeds at 10 meter height in Florida range from 100 to 150 miles per hour. These wind speeds are used to calculate design wind loads on a per square foot basis for Exposure C (open exposed areas) and Exposure B (built-up areas). The design process allows for adjustments to be made in calculating design wind pressures for gable roof overhang.

Design uplift pressures for roof sheathing on building with roof slopes greater than 2 in 12 will range as indicated by the examples below:

EXAMPLE 1:

For Exposure B under the following conditions: (a) Roof height 15 feet to 40 feet, (b) Roof zones 2 an 3, (c) Gable end condition. Design wind pressure ranges from - 43.8 psf at 15 feet above ground under winds of 100 mph to -107 psf at 40 feet above ground and winds of 150 mph.

EXAMPLE 2:

For Exposure C under the following conditions: (a) Roof height 15 feet to 40 feet, (b) Roof zones 2 an 3, (c) Gable end condition. Design wind pressure ranges from – 53.2 psf at 15 feet above ground under winds of 100 mph to -146.4 psf at 40 feet above ground and winds of 150 mph.

Extensive roof sheathing fastening tests at Clemson University (Reinhold 2000 – 2002, McKinley 2001) and at the International Hurricane Center – Florida International University (Reinhold, Alvarez 2003) have compared the Mean Failure Pressure in psf for roof sheathing panels using both the 8d common and the 8d ring shank nails spaced at 6 inches as prescribed by the Florida Building Code. Sheathing consisted of 5/8 inch thick plywood attached to nominal 2x4 Southern Yellow Pine rafters.

The results of these tests were as follows:

(1) **Mean ultimate uplift capacity for panels attached with 8d common nails at 6 inch spacing: 126 pounds per square foot**

(2) **Mean ultimate uplift capacity for panels attached with 8d ring shank nails at 6 inch spacing: 292 pounds per square foot**

This shows a 131% improvement in performance when 8d ring shank nails are used instead of the currently prescribed 8d common nails.

Using data from these tests and a design procedure (Reinhold 2002) to calculate the allowable design uplift pressure for roof sheathing using both types on nails the following results are obtained:

(1) **For 19/32 inch thick plywood sheathing using 8d common nails at 6 inch spacing: 58 psf**

(2) **For 19/32 inch thick plywood sheathing using 8d ring shank nails at 6 inch spacing: 150 psf**

These results show that the currently prescribed 8d common nail would only meet allowable design uplift pressures for some limited roof conditions, roof heights, and only up to wind speeds of 120 mph.

In contrast these results show that sheathing attached with the proposed 8d ring shank nail would perform adequately under all roof conditions and heights, from 15 feet up to 40 feet, including gable ends in any exposure category as used in the 2001 Florida Building Code.

Based on the benefit-cost parameters and the results of comparative tests the simple proposed change would significantly improve roof construction in the High Velocity Hurricane Zone in Florida.

<u>Please explain how the proposed modification meets the following requirements</u>:

1. **Has a reasonable and substantial connection with the health, safety, and welfare of the general public:**

   The proposed modification will reduce the potential for damage to housing and other buildings from the impact of hurricanes. This will in turn contribute to the protection of life and property. These benefits will be obtained at minimal to negligible cost to the public. Therefore the proposed modification will substantially benefit the health, safety and welfare of the general public.

2. **Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction:**

   The proposed modification strengthens and improves the code, and it also provides a better method of construction.

3. **Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities:**

   The proposed modification does not in any way discriminate against existing materials, products, methods or systems on construction. The proposed ring shank nails are readily available from suppliers throughout the country.

4. **Does not degrade the effectiveness of the code:**

On the contrary, the proposed modification improves the effectiveness of the code in meeting its mission of ensuring sound and affordable construction for the residents of Florida.

and 8.

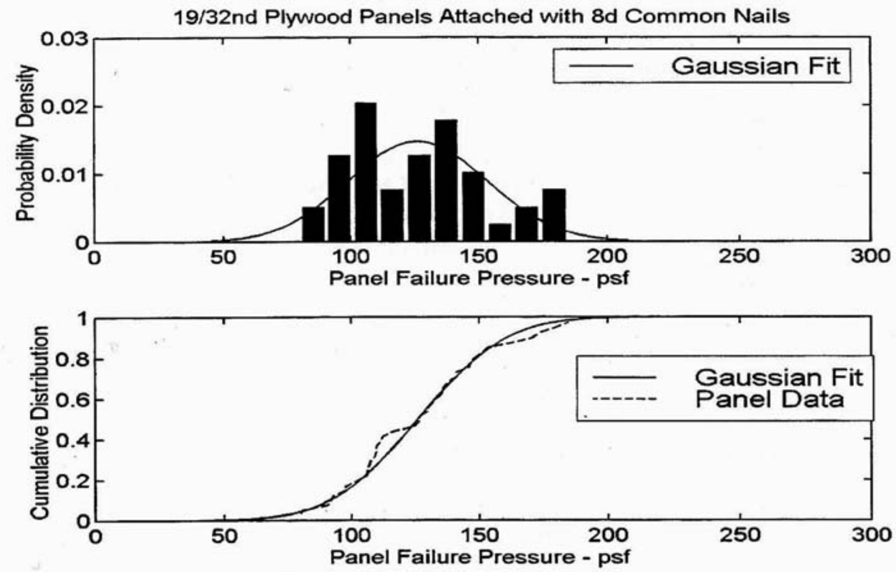

Figure 7. Comparison of Panel Uplift Capacity Results for 8d Common Nails with Normal or Gaussian Distribution

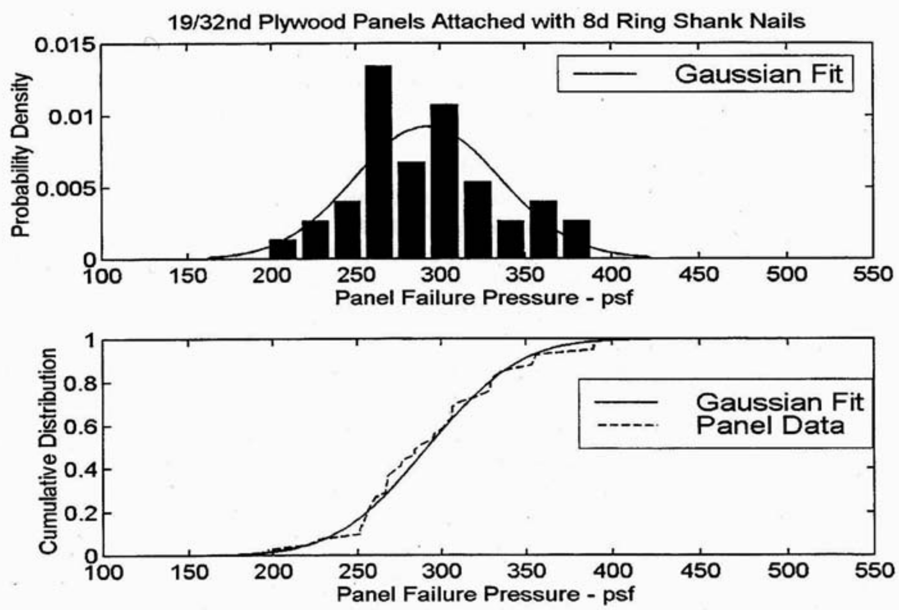

Figure 8. Comparison of Panel Uplift Capacity Results for 8d Ring Shank Nails with Normal or Gaussian Distribution

Form No. 2000-01 Effective date: 11/28/00

Once submitted, the above proposal went through a period of open public commentary where any member of the general public, regardless of professional qualifications or affiliation, was free to submit comments relative to the proposed change using the digital method for posting such comments to the State Building Code Commission web site.

Upon completion of the public commentary period the proposal and all submitted comments were given to a Technical Review Committee of the State Building Code Commission for review and analysis. In June of 2003 the Technical Review Committee recommended that proposed *Modification #856* be approved as submitted at the next meeting of the State Building Code Commission.

> "In October of 2003 the State Building Code Commission upon review of Modification #856 and taking into consideration the recommendation of the Technical Review Committee approved the proposed modification to the Florida Building Code to become effective as of January 1, 2005 in the High Velocity Hurricane Zone".

While the approval of Modification #856 is the culmination of two years [2001/2002 and 2003/2003] of research by the IHRC Team, the process of preparing, submitting and reviewing the modification, straddling two HLMP research periods [2002/2003 and 2003/2004]. This influenced to some degree the specific research agenda proposed by the IHRC Team to DCA for the 2003-2004 grant period. This reinforced the point, often made by the IHRC Team, that the <u>whole HLMP effort must be viewed as a continuum</u> where work done in one year often answers questions, but also discovers a range of other questions that need to be answered while establishing a foundation for future work. To the degree that the HLMP fosters this continuum the whole process is strengthened for the benefit of the residents of hurricane vulnerable communities in Florida and elsewhere.

The following pages show some of the printed media coverage that was recently dedicated to the Florida Building Code modification that will prescribe the 8d ring-shank nail for roof sheathing in the High Velocity Hurricane Zone as of January 1, 2005.

The Miami Herald

SATURDAY, JUNE 19, 2004 | 101ST YEAR, NO. 279 | ©2004 THE MIAMI HERALD | FINAL | 35 CENTS

UP FRONT | HOME CONSTRUCTION

'MAGIC NAILS' HELP KEEP ROOF ON IN HURRICANE

Researchers nailed it: Local building codes will require use of "magic nails" that double a roof's resistance to hurricane winds.

BY MARTIN MERZER
mmerzer@herald.com

It measures 2⅜ inches long, costs less than one cent and goes by the catchy name of "8d ring shank." You'll learn to love it: It could keep the roof over your head, preserve your house and save your life during the next big hurricane.

Researchers at Florida International University have discovered that a fairly common nail — the 8d ring shank — more than doubles the resistance of roofs to hurricane winds.

Builders and regulators agree. Beginning in January, every new home built in Broward and Miami-Dade

• TURN TO NAILS, 2A

■ MORE ONLINE: TO SEE ANIMATION ON HOW WIND FROM A HURRICANE CAN DESTROY A ROOF, GO TO WWW.HERALD.COM/NEWS, CLICK ON FLORIDA

KEEPING A ROOF OVERHEAD

Researchers say the 8d ring shank nail substantially improves the odds of a roof staying in place during a hurricane.

SOURCE: FIU College of Engineering

LYNN OCCHIUZZO/HERALD STAFF

INFORMATION FOR LIFE

The Miami Herald

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UP FRONT

'Magic nails' help keep roofs on

• NAILS, FROM 1A

counties must use these roofing nails.

Within the next 10 years, one million South Floridians will be living under roofs nailed to structures with 8d ring shanks. The extra cost over ordinary roofing nails: less than $10. For an entire house.

"We call these 'magic nails,'" said Ricardo Alvarez, an adjunct professor and research associate at FIU's College of Engineering. "It's a double whammy — it improves the product and it doesn't really cost you any more."

Said Eduardo Camet, president of Paragon Homes, based in Cooper City: "They're great. We're already starting to use them."

THE RINGS

The "magic" is conjured by 16 to 20 rings that girdle the bottom half of the nail, making it look like a cross between a nail and a screw.

In fact, engineers say the ring shank delivers the interlocking holding power of a screw and retains the endurance of a nail, particularly as the plywood sheathing it connects to roof rafters reacts to South Florida's harsh environment.

"As the wood expands and contracts, nails can come out,

PETER ANDREW BOSCH/HERALD STAFF

A BETTER NAIL: FIU Engineering Professor Ricardo Alvarez takes a good look at one.

but this one won't," Alvarez said. "You could try regular screws, but the heads sometimes break off."

Roofers also object to using screws because they take more time to install.

Building on research conducted at Clemson University, Alvarez and a team at FIU's International Hurricane Research Center spent two years testing various nails and screws. They searched for an alternative to the 8d and 10d common bright roofing nails that were previously required by the building code but, in many cases, couldn't stand up to Hurricane Andrew in 1992.

They found that the ring shank, long used for patios and decks, was the answer.

OLD NAILS COME LOOSE

Common bright nails tend to come loose in 120-mph winds like those produced by a mid-Category Three hurricane on the Saffir-Simpson scale. Ring shanks, however, can withstand the 150-mph blasts produced by a high Category Four hurricane, Alvarez said.

Andrew's top sustained wind was 165 mph, making it a Category Five monster, but most residents of Andrew-ravaged South Miami-Dade experienced Category Four winds.

For the technically minded, FIU's research showed that ring shanks improve the resistance of roofs to hurricane-induced "wind uplift" by up to 130 percent.

Beginning Jan. 1, the state's roof sheath nailing standard will require use of the 8d ring shank on all new construction — and on many reroofing jobs, depending on the scope — in Broward and Miami-Dade.

"It doubles the uplift resistance," said Mo Madani, a technical manager for Florida's Building Codes and Standards Office. "The Florida Building Commission approved it because of the benefits."

Ted Berman, an engineer and deputy director of Miami-Dade's Building Code Compliance Office, said he recommended that the state adopt the new standard. "It's much more difficult to pull out," he said of the ring shank.

The nails are widely available, with every 6,000 costing about $56. They can be spaced at the same distances as common bright nails. Builders say the negligible additional cost disappears because roofers can work more efficiently with the ring shank.

Camet, the Broward builder, said homeowners whose roofs need new shingles but not the underlying plywood sheathing might benefit by having a roofer reinforce existing plywood with these nails.

"The only difference is that you need a different type of nailing gun," said Camet, who also serves as vice chairman of the International Hurricane Research Center's board of trustees.

The state's new rule about ring shanks applies only to Miami-Dade and Broward, although every coastal county of Florida faces serious hurricane threats.

"People ask, 'Wouldn't it make sense to use these if you are building a house elsewhere in Florida?'" Alvarez said. "The answer is, 'Yes.'"

el Nuevo Herald

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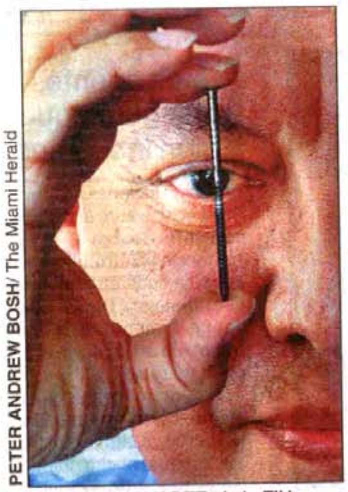
PREMIO ORTEGA Y GASSET

35¢

SABADO 19 DE JUNIO DEL 2004F



PETER ANDREW BOSH/ The Miami Herald

RICARDO ALVAREZ, de la FIU, muestra el nuevo clavo con estrías.

Un clavo más seguro contra los huracanes

Será obligatorio a partir del próximo 1ro de enero

VIVIANA MUÑOZ
El Nuevo Herald

En unos meses entrarán en efecto cientos de cambios en el Código de Construcción del sur de la Florida. Uno de éstos, recomendado por un grupo de investigadores de la Universidad Internacional de la Florida, busca fortalecer los techos de nuevas construcciones en un 130 por ciento. Se trata de un clavo aparentemente común y corriente, conocido en la jerga de los constructores como "el de los anillos".

El nuevo clavo, que ya está en el mercado, tiene un largo de 2". En vez de ser liso, su superficie tiene estrías, lo que le da mayor tracción en la madera.

Ricardo Alvarez, subdirector del Centro Internacional de Investigación de Huracanes en FIU, dijo que utilizando este nuevo clavo en el techo de una casa se puede resistir un huracán de categoría 4, con vientos de 131 a 155 millas por hora.

Los clavos usados hasta el momento soportan un huracán categoría 3, de 111 a 130 millas por hora.

Los cambios entrarán en efecto el próximo 1ro de enero, lo que significa que por ley este nuevo clavo tiene que ser utilizado en la instalación de las planchas de plywood que son la base sobre la que descansan las tejas de un techado.

"El techo es la primera línea de defensa en una casa frente a un huracán", afirmó Alvarez. "Si el techo cede, ya nada frena el embate de un huracán", agregó.

Por favor, pase a la página siguiente

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MIAMI

PREMIO ORTEGA Y GASSET

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SABADO 19 DE JUNIO DEL 2004F

Nuevo clavo para techos puede salvar vidas

VIENE DE LA PRIMERA PAGINA

Se calcula que a lo largo de los próximos 10 años se fortalezcan los techos de unas 350,000 viviendas del sur de la Florida, lo cual representa un millón de habitantes.

"Este cambio potencialmente puede salvar miles de vidas, además de ahorrar millones de dólares en posibles pérdidas materiales", enfatizó Alvarez, cuyo equipo probó docenas de clavos diferentes durante más de un año.

El experto dijo que el nuevo clavo no sólo fortalecerá más los techos, sino que también es más productivo para las compañías constructoras.

"En este momento se utilizan dos tipos diferentes de clavos. Con este nuevo clavo no hay necesidad de otro tipo, lo que hace más productivo el trabajo para empresas que construyen viviendas en gran escala", indicó Alvarez.

El presidente electo de los Latin Builders, Augusto Gil, afirmó que Miami-Dade y Broward tienen un código de construcción más estricto que el resto del estado "debido a la experiencia con Andrew, y porque los ciclones por lo general han entrado por Monroe, Dade y Broward".

"En la industria estamos a favor de que todo lo que sea para fortalecer las viviendas ante huracanes", subrayó Gil, presidente de Gil Development, refiriéndose al nuevo clavo.

Eduardo Camet, presidente de la compañía constructora MH Homes y vicepresidente de la junta directiva del Centro Internacional de Investigación de Huracanes de la FIU, dijo que este es un ejemplo claro de cómo el Centro Internacional de Investigación de Huracanes en FIU produce investigaciones prácticas y con sentido económico.

También es más productivo para las compañías constructoras

"Esto beneficiará la comunidad del sur de la Florida y otras poblaciones vulnerables a estas tormentas", indicó Camet. "Este es el tipo de investigación en que debían de invertir los gobiernos y el sector privado".

Los investigadores del Laboratorio de Mitigación Estructural de FIU experimentaron con más de 10 tipos diferentes de clavos durante dos años. Los clavos fueron probados más de 1,200 veces, con situaciones en las que se simulaban las condiciones de huracanes. Estos experimentos se hicieron en cámaras de vacío para simular la succión del viento. También se medían factores como la humedad de la madera y la fuerza necesaria para sacar un clavo.

El cambio fue aprobado por el Comité de Regulación de Construcción del estado de la Florida, para ser efectivo a partir del próximo año.

"Hice un estudio de la propuesta y la encontré beneficiosa para ser incluida en los requisitos del Código de Construcción", afirmó el ingeniero civil Theodore Berman, director adjunto de la Oficina de Administración del Código de Construcción (BCCO).

"Ellos hicieron una serie de pruebas que demostraron la conveniencia de usar este tipo de conector, porque tiene más poder de aguante debido a sus estrías. Un clavo normal es liso y aguanta la madera en fricción. El clavo con estrías ofrece resistencia similar a la de un tornillo", indicó Berman.

"Quien vaya a solicitar un permiso de construcción después del 1ro de enero próximo tendrá que cumplir con este requisito", indicó Berman.

El código de construcción será publicado con los cambios, en la sección 2322, y el nuevo clavo es uno de los más de 500 cambios que entrarán en vigor.

Los principales novedades en el código son de resistencia al fuego, energía, plomería, electricidad y mecánica.

Berman agregó que la Oficina de Administración del Código de Construcción ofrecerá seminarios a los constructores, inspectores y arquitectos e ingenieros sobre los cambios al Código de Construcción.

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Executive Summary

For the grant period of July 1, 2003 through June 30, 2004 the IHRC team proposed to build upon work done in 2002-2003 by including some of the following areas of research under the specific topic of *Performance Modifiers in the Mitigation of Roof Damage:*

(a) Research and development for a *Wall-of-Wind* [WOW] study. This includes using different sources to generate hurricane strength winds that closely replicate the wind shear and other wind elements found in natural wind [fields]. The main objective of this is to allow the testing of full-scale housing components and assemblies in order to develop new and effective applications for hurricane loss mitigation methods and techniques applicable to site-built housing.

(b) Continued testing of a variety of fasteners such as screw-shank nails, screw-nails, clipped-head ring shank nails and others. The objective of these tests is to increase the database of performance levels for a variety of fasteners that would be useful to builders and designers in Florida and other hurricane-vulnerable regions.

(c) Cost-analysis for the various fasteners tested to compare with the cost of using fasteners prescribed by pertinent building codes. This will be helpful in identifying cost-effective loss-reduction alternatives.

(d) Research and development of modified-design for drip-edge roof flashing that may contribute to reducing potential damage to shingle roofs under hurricane impact.

(e) Research and development into the effectiveness of edge-spoilers, to be installed on the gable roof edge, in reducing the sequence of events that results in damage to the roof covering under hurricane impact.

(f) Assess the performance of various types of roof covering, such as clay tiles or shingles, under various intensities of wind to determine the feasibility of improving such performance by developing improved methods for installation.

(g) Research of performance improvement of existing roofs built prior to the current applicable building code through various retrofit measures. The main objective of this specific track is to explore the viability of improving the existing housing stock as a way of achieving more comprehensive hurricane loss-reduction for housing.

(h) Benefit-cost analysis for various performance modifiers.

The sections that follow summarize key activities under each of the areas of research carried-out under the track of *Hurricane Loss Reduction Devices and Techniques – Performance Modifiers in the Mitigation of Roof Damage.*

3.2.a RESEARCH AND DEVELOPMENT FOR A WALL-OF-WIND STUDY

Since 2000 the IHRC has focused most of its HLMP research, related to the search for *hurricane loss reduction devices and techniques,* on how to improve the performance of the various components of the roof assembly, from the roof covering and sheathing, to the supporting structure and its connection to the walls and the rest of the house structure. This is based on the roof as an integral component of the house *building envelope* and truly the first line of defense under the impact of a hurricane.

Toward this end the IHRC Team has used an approach involving three key components:

(a) Experimental studies involving reduced-scale testing of models in a boundary-layer wind tunnel [BLWT], with the objective of understanding the pressure distribution on a roof resulting from the interaction of a wind-field with a house.

(b) Experimental studies involving the testing of full-size (1:1 scale) specimens of roof assemblies or components using an artificial source of wind to simulate the velocity and behavior of hurricane winds. In most cases the source of wind has been air boats, which at times have been complemented by the use of contraction cones and other devices.

(c) Analytical studies based on data obtained from the experimental studies mentioned above.

The use of airboats as a source of wind for the full-size experimental tests has several limitations, even though wind speeds in excess of 125 mph have been obtained. As a result these tests have been able to simulate the force of the wind producing realistic wind loads, however due to the limitations resulting from the size and shape of the propellers used, the maximum propeller-tip mach speed, and other characteristics it has been difficult to simulate the behavior of hurricane wind-fields. In addition to these problems of a scientific nature, the use of air boats has other limitations of a mechanical nature. These limitations are inherent with the use of aircraft air-cooled engines including overheating, noise, torque and the “shape” of the actual wind-field produced.

To remedy these problems the IHRC team embarked in a search for alternative solutions during the 2003-2004 research grant period. The focus of this search for alternative solutions has been the *wall-of-wind [WOW]*, as a wind-generating apparatus capable of producing even higher wind speeds than those obtained up to now by using airboats, but more importantly also capable of simulating the characteristics of a hurricane wind-field with much higher accuracy than has been possible up to now with airboat as the source of wind.

The wall-of-wind [WOW] includes several significant differences with the airboats used before, these include:

(a) The use of water-cooled automotive engines, in order to resolve the overheating problem and to simplify maintenance;

(b) The use of specially shaped propeller blades designed for higher blade-tip mach speeds and capable of moving much higher volumes of air. The result of this is a higher and faster flow rate producing wind velocities in excess of 150 mph;

(c) The use of larger diameter propellers. The intent is to go from the 60” – 62” diameter used before to propellers of 78” to 82” diameter;

(d) Using two counter-rotating propellers mounted on the same axis. This will deliver a more streamlined and laminar flow of wind resulting on a wind-field that more closely replicates the natural characteristics of a hurricane;

(e) Using two sets of double counter-rotating propellers, one on top of the other, to effectively achieve a true *wall-of-wind* that projects more than fifteen [15’] above the ground. This also contributes to the delivery of a more realistic wind-field, while also allowing for the testing of larger specimens;

(f) Outfitting the apparatus with straight-section ducting and movable vanes to further improve the outflow of wind while adding the capability for creating variations in direction and a suitable gust field, or for inducing some degree of turbulence for more realistic results.

Based on the design concept outlined above the IHRC team conducted an extensive search for potential manufacturers or vendors who would be capable of supplying a prototype of said wall-of-wind apparatus. This search included suppliers to the movie industry and well as several airboat manufacturers who are working with automotive engines and counter-rotating propellers. In April 2004 we identified one airboat manufacturer, located in Cocoa, Florida, who had actually built a so-called *wind machine* for a commercial testing laboratory in central Florida. In fact this manufacturer had also previously supplied FIU with airboats to be used in research related to the Everglades restoration project.

Ricardo A. Alvarez, HLMP PI and Project Director at FIU, together with Timothy Reinhold, a consultant to the project from Clemson University, and Eddy Rodriguez from FIU Vehicle Services Department, visited the manufacturer in April to test various pieces of equipment.

These members of the IHRC team used a pitot tube and a handheld manometer to test the wind speed generated by an airboat equipped with two counter-rotating high-flow three-bladed propellers driven by a high-performance 540 hp water-cooled automotive engine. The front propeller was 82” in diameter and the back one 78” in diameter. The pitot tube/manometer assembly measured wind speeds as high as 145 mph before reaching the limit of its measuring range. The IHRC team concluded that wind speeds in excess of 150 mph had been obtained since the recording assembly had reached its limit while the airboat engine had not yet reached its maximum rpm capability.

Based on these findings the IHRC team has ordered the construction of on a wall-of-wind [WOW] apparatus. Unfortunately, due to the time limitations resulting from the shortened research period, the purchase order was issued so close to the end of the research period that it became necessary for the IHRC team to request a *no-cost-extension* from DCA in order to be able to use monies from the 2003-2004 grant to pay for this equipment.

Concurrently with this research the IHRC team also conducted a model test, using a reduced-scale WOW device constructed of model-airplane engines and 12x8 propellers and a universal variable prop-speed control, refer to Figure 1. Such model work indicates a minimum array of four [2 x 2] propeller sets will be needed for a fully functional WOW system capable of producing a large enough wind-field flow to encompass sufficient area to engulf full-scale test specimens. This will require two individual WOW apparatus, as described above, working side by side. This array will generate an initial wind field of approximately 14 ft x 14 ft about 1 ft above the ground at the propellers, but somewhat larger as it impacts a test specimen situated a few feet away from the apparatus.

The minimum WOW array just described will provide the IHRC team with a platform for conducting a wide range of tests involving roofing components, various structural assemblies and elements of the building envelope in general. In future years, subject to funding availability, this WOW concept could expand to include much larger arrays, perhaps using fixed installations rather that the airboat platforms and propellers sets of 3 x 6 that would be capable of producing wind fields of approximately 20’ x 40’ or even larger. Such a facility, which would be unique in Florida, would go a long way toward promoting a wide range of research initiatives with the objective of improving the performance of housing under the impact of hurricanes, thus fulfilling the mission of the HLMP for the benefit of residents of vulnerable communities everywhere.

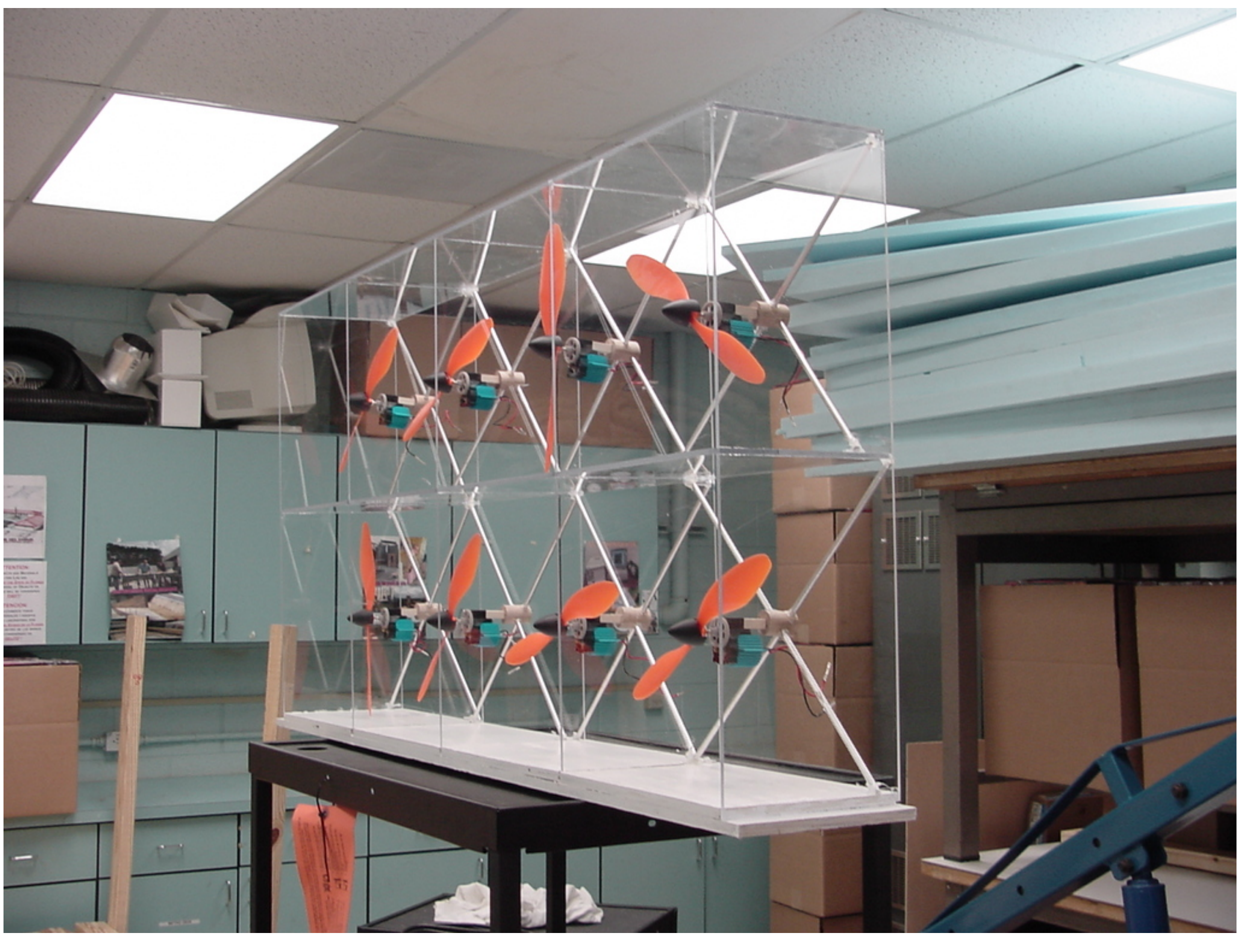

Figure 1. Minimum Wall-of-Wind Array

3.2.b CONTINUED TESTING OF ROOF-SHEATHING FASTENER

This area of research, involving work over the previous two grant periods [2001/2002 and 2002/2003], built on the foundation of prior research at other academic institutions outside Florida, had led to the highly successful modification of the Florida Building Code to become effective as of January 1, 2005 in the High Velocity Hurricane Zone. The tremendous benefits of the building code modification for residents of vulnerable communities in Florida can never be overstated. Continued objectives under this specific research topic, included the following:

a) Continue research to assess the effectiveness of using the 8d ring-shank nail to improve the performance of roof sheathing in areas of Florida outside the High velocity Hurricane Zone.

b) Continue research to asses the effectiveness of a range of various fasteners, used for roof sheathing, in improving [or not] the performance of roof sheathing under hurricane winds.

Work Completed during the 2003-2004 HLMP Grant Period

In view of the limited time allowed for this type of research, as a result of the late date by which the grant contract was actually executed, the IHRC team decided to concentrate its efforts on researching the effectiveness of the 8d ring-shank nail in improving the performance of roof sheathing under the impact of hurricanes, outside the High Velocity Hurricane Zone. Time permitting the IHRC team had planned to tackle the assessment of effectiveness of a range of various other fasteners, but this was not the case during this particular HLMP grant period.

Methodology

The methodology used was based on a comparative study of the performance of roof sheathing panels constructed of ½" plywood attached to a structure of 2x4 rafters at 2'-0" on center, using the nailing schedule prescribed by the Florida Building Code for locations outside the High Velocity Hurricane Zone. The nailing schedule currently prescribes 8d nails at 6" o.c. at the edges of the sheathing panel and at 12" o.c. on the field. A base-line for this study was established using 8d common bright [smooth-shank] nails and the results where then compared to another set of tests where the nail was substituted by the 8d ring-shank nail meeting the minimum specification prescribed by the modified Florida Building Code [to become effective January 1, 2005 in the High Velocity Hurricane Zone].

Given the extent of previous tests the IHRC team decided to create a base-line by testing fifty [50] panels, and the comparison by testing an additional fifty [50] panels.

The methods used for these tests were the same as had been used before. This method involves the following:

a) Full size (4' x 8") roof sheathing panels are built using a precision frame to ensure uniformity of product and for quality assurance purposes.

b) The panels consist of ½" CDX plywood attached to a structure of 2"x4" Southern Yellow Pine (SYP) rafters at 2'-0" on center. A sheet of 6 mil [minimum] vinyl is installed between the plywood and the rafters with the purpose of assuring a perfect seal when the panels are tested in the vacuum chamber.

c) Nailing is done using the specified nail, either 8d common bright or the 8d ring shank, driven by means of a pneumatic power tool [nailing gun]. In order to ensure the nailing schedule meets specifications, the plywood sheathing is previously marked along the center line of each rafter and at the appropriate spacing [6" or 12"] using a previously notched heavy aluminum ruler.

d) For quality assurance purposes nailing is inspected to detect "shiners", meaning nails that missed a rafter altogether or partially because of being driven at an angle, and also to detect overdriven nails, meaning those whose heads have penetrated the top lamination of the plywood sheet. Any test specimens showing these defects are discarded for other uses.

e) The structural members are then identified by marking them with the letters A through E going from left to right as the panel assembly lays upside down [the rafters on top].

f) The test specimen is then mounted in the vacuum chamber apparatus and vinyl sheet is attached to apparatus with adhesive tape to ensure total air-tightness.

g) The moisture content of each 2”x4” rafter is measured, using a digital electronic moisture meter. These readings are then recorded for each test.

h) With the test specimen sealed in place on the vacuum chamber the initial pressure is recorded. Then the vacuum chamber is activated until failure of the roof sheathing panel occurs [this happens when the sheathing separates from the rafters because the negative pressure applied exceeds the uplift capacity of the fasteners]. At that time the final pressure reading is also recorded. The difference between final and initial pressure is the applied pressure. All pressures are recorded in pounds per square foot [psf].

i) Before removal of the failed specimen from the vacuum chamber it is inspected in order to determine and record the type of failure that took place. This inspection also looks for failure due to “nail-head-pull-through”, meaning the nail remains embedded in the structural rafter, but the plywood has pulled out with the nail-head pulling right through the plywood laminations. A record is made of these types of failures.

j) As a last step some of the rafters with still-embedded nails are saved, before the failed specimen is discarded. These saved rafters are then used for “nail-pull-out” tests using a mechanical device with a digital readout [force meter]

This process is repeated until all test specimens are tested. It is important to note that the whole process must observe a protocol of staggered activities. This means that test specimens must be fabricated as close as possible to the time they will be subjected to testing on the vacuum chamber. The main reason for this is that when test specimens are fabricated in large numbers and, for any reason, they can not be tested within the same day of within a few hours the moisture content and other characteristics may change as a result of the daily temperature/humidity cycles and this may introduce a variability factor that could affect test results for specific specimens.

Initial Findings

A key objective of the tests conducted was to compare the performance of ½” plywood roof-sheathing panels under hurricane winds when constructed with 8d common bright [smooth-shank] nails versus those constructed using the 8d ring-shank nail. The nailing schedule to be used is 6” on center at panel edge and 12” on center on the field.

Such a comparison would be useful in assessing the feasibility of using the 8d ring-shank nail instead of the 8d common bright in those 64 counties in Florida that are outside the High velocity Hurricane Zone, provided the benefit-cost analysis justifies any cost differential [meaning, in case the cost is higher that under current methods of construction as prescribed by the Florida Building Code].

Some initial findings from these tests comparing fifty full-scale roof sheathing panels using each type of nail, include the following:

a) Average applied pressure, up to the point of panel failure, for ½" panels built with the 8d common bright [smooth-shank] nails was 107.8 psf.

Avrg. Uplift Capacity for ½" Plywood w/8d CB = 107.8 psf

b) Average applied pressure, up to the point of panel failure, for ½" panels built with the 8d ring-shank nails was 139.8 psf.

Avrg. Uplift Capacity for ½" Plywood w/8d RS = 139.8 psf

c) There was an improvement in performance when using the 8d ring-shank nail instead of the building code prescribed 8d common bright. The improvement in performance was in the order of 29.7%.

d) While the total numbers of nails pulled out of the rafters, totally or partially, remained basically the same between the two sets of tests, the number of nail-head pull-through increased by an average factor of 22.2% when using the ring-shank nail instead of the 8d common bright. This is mainly due to the holding capacity of the ring-shank nail exceeding the shear strength of the ½" plywood.

e) One hundred percent [100%] of failures, regardless of the type of nail used, during these tests occurred at the intermediate [B, C and D] rafters, but never at the edge rafters [A and E]. This can be attributed to the tributary area per nail being that much larger in the field than at the edges of each panel. The tributary area per nail at the edge rafters [A and E] is only 0.5 square foot. The tributary area per nail at the end of the panel for intermediate rafters [rafters B, C and D] is 1.0 square foot, while the per-nail tributary area of inside nails at intermediate rafters if 2.0 square foot.

f) Based on the total applied pressures and the per-nail tributary areas given above the loads applied per nail at the moment of failure are shown below:

Table 1.Load Applied per Nail

Nail Type	***Nail Position***	***Rafter***	***Tributary Area/Nail***	***Total Applied Load/Nail***
CB	ANY	A	0.5 sf	53.9 lbs
CB	END	B,C,D	1.0 sf	107.8 lbs
CB	INSIDE	B,C,D	2.0 sf	215.6 lbs
CB	ANY	E	0.5 sf	53.9 lbs
RS	ANY	A	0.5 sf	69.9 lbs
RS	END	B,C,D	1.0 sf	139.8 lbs
RS	INSIDE	B,C,D	2.0 sf	279.6 lbs
RS	ANY	E	0.5 sf	69.9 lbs

Above values show that inside nails at intermediate rafters take uplift loads that are four times higher than those being resisted by nails at the edge of the plywood sheathing over the first and last rafters [A and E].

One initial conclusion to be drawn from this is that the performance of the roof sheathing panel under hurricane winds could improve if the nailing schedule went from the current spacing to one that is 6” o.c. throughout the panel. This would cut the per-nail tributary area for all inside nails at the intermediate rafters, resulting in a much lower total load being resisted by those nails.

g) This suggest this line of research will need to be continued into the 2004-2005 HLMP grant period, in order to ascertain what added performance enhancement may result from reducing the maximum load per nail.

Results for the 2003-2004 outside the high Velocity Hurricane Zone roof sheathing tests can be found in the following tables.

Table 2. Pressure Test Results for the Common Bright Nail: Outside the High Velocity Hurricane Zone (Plywood: 1/2" thick; Nailing schedule: int.: 12"O.C. Ext.: 6" O.C.)

Panel #	Initial Pressure	Final Pressure	Applied Pressure
001-CB	-11.8 psf	-132.8 psf	121 psf
002-CB	-12 psf	-127.4 psf	115.4 psf
003-CB	-12.9 psf	-100.3 psf	87.4 psf
004-CB	-8.4 psf	-104 psf	95.6 psf
005-CB	-7 psf	-108 psf	101 psf
006-CB	-8.3 psf	-100.5 psf	92.2 psf
007-CB	-7.2 psf	-120.4 psf	113.2 psf
008-CB	-7.4 psf	-102.5 psf	95.1 psf
009-CB	-7.7 psf	-109.7 psf	102 psf
010-CB	-9.2 psf	-104 psf	
011-CB	-7.2 psf	-120.4 psf	113.2 psf
012-CB	-7.7 psf	-98.3 psf	90.6 psf
013-CB	-8.3 psf	-101.9 psf	93.6 psf
014-CB	-12.3 psf	-163.5 psf	151.2 psf
015-CB	-13.1 psf	-110.3 psf	97.2 psf
016-CB	-13.5 psf	-90.9 psf	77.4 psf
017-CB	-13.4 psf	-131.6 psf	118.2 psf
018-CB	-11.8 psf	-115.2 psf	103.4 psf
019-CB	-10.6 psf	-115 psf	104.4 psf
020-CB	-8.9 psf	-134.8 psf	125.9 psf
021-CB	-11.4 psf	-104.8 psf	93.4 psf
022-CB	-10.5 psf	-160.2 psf	149.7 psf
023-CB	cb	-107.5 psf	97 psf
024-CB	-12.5 psf	-137.3 psf	124.8 psf
025-CB	-10.5 psf	-144.2 psf	133.7 psf
026-CB	-7.7 psf	-124.3 psf	116.6 psf
027-CB	-10.3 psf	-119.7 psf	109.4 psf
028-CB	-9.8 psf	-149.3 psf	139.5 psf
029-CB	-11.3 psf	-114 psf	102.7 psf
030-CB	-10.3 psf	-117.8 psf	107.5 psf
031-CB	-5.9 psf	-116.7 psf	110.8 psf
032-CB	-6.4 psf	-128.4 psf	122 psf
033-CB	-5.3 psf	-149.1 psf	143.8 psf
034-CB	-5.5 psf	-98.6 psf	93.1 psf
035-CB	-6.7 psf	0 psf	-6.7 psf
036-CB	-5.3 psf	-99.8 psf	94.5 psf

Table 2 (continued)			
Panel #	**Initial Pressure**	**Final Pressure**	**Applied Pressure**
037-CB	-7.1 psf	-156.5 psf	149.4 psf
038-CB	-8.7 psf	-116.7 psf	108 psf
039-CB	-5.4 psf	-108.5 psf	103.1 psf
040-CB	-6.9 psf	-129.2 psf	122.3 psf
041-CB	-8 psf	-111.5 psf	103.5 psf
042-CB	-8.1 psf	-94.9 psf	86.8 psf
043-CB	-7.5 psf	-118.4 psf	110.9 psf
044-CB	-6.5 psf	-115.4 psf	108.9 psf
045-CB	-6.4 psf	-134.9 psf	128.5 psf
046-CB	-7 psf	-143.9 psf	136.9 psf
047-CB	-6.7 psf	-115.5 psf	108.8 psf
048-CB	-8.6 psf	-125.9 psf	117.3 psf
049-CB	-9.2 psf	-101.1 psf	91.9 psf
050-CB	-9.3 psf	-89 psf	79.7 psf
Average Applied Pressure 107.8			

Table 3. Moisture Test Results for the Common Bright Nail: Outside the High Velocity Hurricane Zone (Plywood: 1/2" thick; Nailing schedule: int.: 12"O.C. Ext.: 6" O.C.)

Panel #	Member A	Member B	Member C	Member D	Member E
001	11.1%	14.5%	16.9%	16.8%	15.2%
002	14.1%	13.7%	13.2%	8.8%	13.5%
003	14.4%	16.1%	14.7%	15.6%	14.1%
004	15.8%	15.7%	12.0%	19.5%	16.1%
005	18.5%	17.5%	14.5%	16.2%	13.4%
006	15.8%	14.6%	15.1%	15.5%	15.6%
007	17.5%	15.9%	16.0%	17.3%	13.9%
008	14.8%	12.3%	8.7%	14.2%	16.6%
009	13.6%	14.2%	14.6%	16.2%	14.1%
010	13.0%	14.1%	15.8%	15.9%	15.8%
011	13.5%	13.2%	15.0%	13.4%	13.6%
012	13.9%	13.8%	13.0%	15.1%	17.6%
013	15.1%	15.8%	16.3%	15.2%	15.6%
014	15.0%	11.3%	16.0%	17.0%	14.0%
015	10.8%	15.8%	16.9%	13.6%	16.1%
016	17.5%	16.2%	17.1%	12.7%	16.6%
017	16.0%	15.7%	18.6%	13.7%	14.2%
018	14.6%	16.3%	16.2%	14.8%	13.8%
019	14.8%	12.7%	16.4%	14.7%	14.6%
020	14.3%	14.7%	16.7%	13.8%	14.0%
021	10.7%	15.8%	15.7%	15.7%	13.3%
022	12.0%	10.7%	9.5%	14.2%	15.2%
023	16.9%	15.6%	14.4%	15.6%	14.1%
024	14.8%	14.1%	17.6%	13.0%	13.0%
025	14.2%	14.4%	16.1%	15.2%	16.0%
026	15.8%	9.0%	14.3%	14.4%	15.7%

Table 3 (continued)					
Panel #	**Member A**	**Member B**	**Member C**	**Member D**	**Member E**
027	11.0%	15.7%	14.8%	11.9%	14.7%
028	16.1%	14.8%	15.8%	14.7%	14.3%
029	15.7%	13.9%	13.2%	13.9%	11.5%
030	15.6%	17.8%	12.7%	11.2%	14.4%
031	11.0%	13.7%	15.3%	12.4%	14.9%
032	13.3%	14.9%	11.0%	12.4%	9.3%
033	14.0%	11.0%	12.8%	13.3%	14.7%
034	13.5%	14.9%	15.0%	13.8%	14.2%
035	12.7%	15.7%	16.0%	15.4%	10.3%
036	11.7%	14.2%	14.0%	11.2%	13.3%
037	15.1%	14.4%	14.1%	13.4%	11.0%
038	12.3%	12.2%	12.7%	13.4%	14.7%
039	11.7%	14.6%	14.2%	13.8%	14.2%
040	14.8%	14.1%	12.4%	12.8%	13.5%
041	14.8%	11.4%	12.8%	14.8%	14.8%
042	12.4%	11.8%	14.8%	14.0%	13.7%
043	11.5%	14.6%	14.6%	14.8%	14.9%
044	14.6%	15.2%	15.1%	12.8%	15.6%
045	14.0%	15.1%	14.8%	14.0%	11.1%
046	14.3%	13.6%	14.9%	13.2%	14.8%
047	14.9%	14.9%	14.8%	14.8%	15.0%
048	15.9%	16.2%	11.7%	14.8%	16.1%
049	15.0%	15.7%	15.6%	16.0%	14.6%
050	14.6%	15.0%	12.7%	15.8%	14.7%

Table 4. Nail Pullout Test Results for the Common Bright Nail: Outside the High Velocity Hurricane Zone (Plywood: 1/2" thick; Nailing schedule: int.: 12"O.C. Ext.: 6" O.C.)

Panel #	A	B	C	D	E
001					
002					
003					
004					
005					
006					
007					
008					
009					
010					
011					
012					
013					
014					
015				243.85	
016				89.76	
017		66.5			

Table 4. (Continued)					
Panel #	A	B	C	D	E
018				113.59	
019			155.64		
020			187.52		
021			114.95		
022					
023	27.23				
024			307.71		
025			22.27		
026				88.18	
027				377.67	
028				13.74	
029		55.67			
030				42.78	
031					
032					
033					
034					
035			266.34		
036		447.05			
037				229.19	
038		255.31			
039					
040					
041					
042					
043					
044					
045					
046					
047					
048				447.79	
049				214.31	
050			217.55		

Table 5. Pressure Test Results for the Sheather Plus (Ring Shank) Nail: Outside the High Velocity Hurricane Zone (Plywood: 1/2" thick; Nailing schedule: int.: 12"O.C. Ext.: 6" O.C.)

Panel #	Initial Pressure	Final Pressure	Applied Pressure
001-SP	5.6 psf	-109.7 psf	115.3 psf
002-SP	6.9 psf	-114 psf	120.9 psf
003-SP	4.9 psf	-131.6 psf	136.5 psf
004-SP	5 psf	-144.9 psf	149.9 psf
005-SP	5.3 psf	-160.7 psf	166 psf
006-SP	5.2 psf	-190.2 psf	195.4 psf
007-SP	5.7 psf	-139 psf	144.7 psf
008-SP	5.5 psf	-89.7 psf	95.2 psf

Table 5. (Continued)			
Panel #	Initial Pressure	Final Pressure	Applied Pressure
009-SP	6.3 psf	-144.2 psf	150.5 psf
010-SP	7.1 psf	-184.5 psf	191.6 psf
011-SP	0.4 psf	-181.3 psf	181.7 psf
012-SP	-0.5 psf	-107 psf	106.5 psf
013-SP	0.4 psf	-116.8 psf	117.2 psf
014-SP	-1.1 psf	-166.1 psf	165 psf
015-SP	-0.8 psf	-155 psf	154.2 psf
016-SP	0 psf	-140.9 psf	140.9 psf
017-SP	1.9 psf	-176 psf	177.9 psf
018-SP	3.8 psf	-148.1 psf	151.9 psf
019-SP	1.3 psf	-144.7 psf	146 psf
020-SP	1.4 psf	-125.6 psf	127 psf
021-SP	-10.1 psf	-162.3 psf	152.2 psf
022-SP	-9.8 psf	-161.6 psf	151.8 psf
023-SP	-9 psf	-150.3 psf	141.3 psf
024-SP	-9.4 psf	-155.2 psf	145.8 psf
025-SP	-8.4 psf	-145.2 psf	136.8 psf
026-SP	-7.8 psf	-148.8 psf	141 psf
027-SP	-6.8 psf	-146.4 psf	139.6 psf
028-SP	-8 psf	-128.5 psf	120.5 psf
029-SP	-6.8 psf	-132.8 psf	126 psf
030-SP	-6.8 psf	-148.2 psf	141.4 psf
031-SP	-8.7 psf	-147.3 psf	138.6 psf
032-SP	-6.3 psf	-143.3 psf	137 psf
033-SP	-7.2 psf	-139.7 psf	132.5 psf
034-SP	-5.5 psf	-163.6 psf	158.1 psf
035-SP	-4 psf	-154.8 psf	150.8 psf
036-SP	-3.8 psf	-119.8 psf	116 psf
037-SP	4 psf	-103.7 psf	107.7 psf
038-SP	4.7 psf	-140.2 psf	144.9 psf
039-SP	4.7 psf	-95.4 psf	100.1 psf
040-SP	4.4 psf	-148.1 psf	152.5 psf
041-SP	-5 psf	-170.7 psf	165.7 psf
042-SP	-6.9 psf	-148.8 psf	141.9 psf
043-SP	-5.5 psf	-157.4 psf	151.9 psf
044-SP	-2 psf	-137.5 psf	135.5 psf
045-SP	-2.1 psf	-92.3 psf	90.2 psf
046-SP	-2.2 psf	-125.6 psf	123.4 psf
047-SP	-1.1 psf	-127.2 psf	126.1 psf
048-SP	-0.9 psf	-154.2 psf	153.3 psf
049-SP	-2 psf	-107.5 psf	105.5 psf
050-SP	-0.3 psf	-120.2 psf	119.9 psf
Average Applied Pressure 139.8			

Table 6. Moisture Test Results for the Sheather Plus (Ring Shank) Nail: Outside the High Velocity Hurricane Zone
(Plywood: 1/2" thick; Nailing schedule: int.: 12"O.C. Ext.: 6" O.C.)

Panel #	Member A	Member B	Member C	Member D	Member E
001	18.2%	19.4%	19.6%	18.7%	20.4%
002	18.7%	19.9%	18.3%	19.0%	19.7%
003	19.6%	17.9%	16.6%	19.9%	18.9%
004	18.5%	18.1%	16.3%	19.4%	18.7%
005	18.4%	16.0%	17.3%	19.4%	17.4%
006	17.0%	19.7%	17.9%	20.0%	20.0%
007	17.6%	17.3%	15.1%	18.1%	18.1%
008	17.0%	17.8%	14.6%	17.4%	18.4%
009	17.3%	18.2%	17.8%	19.4%	20.0%
010	12.2%	13.0%	14.2%	12.4%	14.9%
011	13.2%	13.2%	15.6%	15.4%	16.5%
012	15.1%	14.8%	15.9%	14.7%	15.0%
013	15.1%	15.2%	14.7%	15.1%	16.4%
014	13.7%	15.6%	15.4%	15.2%	15.6%
015	14.0%	15.0%	12.4%	13.8%	15.2%
016	14.6%	14.9%	14.2%	14.9%	15.4%
017	15.0%	15.0%	15.9%	12.9%	14.9%
018	14.8%	15.3%	15.1%	15.3%	15.9%
019	14.7%	13.2%	15.1%	15.6%	15.4%
020	14.7%	15.0%	13.5%	13.3%	14.9%
021	17.9%	19.9%	20.2%	20.5%	19.4%
022	20.0%	21.1%	17.9%	19.9%	19.0%
023	19.0%	20.8%	20.3%	17.3%	20.0%
024	18.8%	16.3%	21.4%	21.4%	21.4%
025	18.7%	19.6%	20.2%	20.3%	19.6%
026	19.6%	20.9%	20.3%	20.0%	19.7%
027	22.0%	19.6%	19.6%	19.6%	19.4%
028	15.7%	21.7%	19.7%	20.0%	20.9%
029	20.5%	19.4%	18.8%	17.2%	19.6%
030	21.4%	20.6%	20.3%	21.2%	17.9%
031	20.3%	20.5%	17.4%	17.9%	20.0%
032	20.9%	20.9%	15.2%	19.7%	19.9%
033	18.7%	19.9%	17.8%	19.6%	20.2%
034	20.0%	19.9%	17.5%	15.1%	21.1%
035	18.1%	17.2%	18.3%	18.7%	18.1%
036	19.6%	17.9%	16.3%	17.4%	16.3%
037	18.2%	16.3%	14.9%	17.9%	18.2%
038	17.2%	14.2%	15.2%	17.6%	18.2%
039	16.3%	19.0%	12.9%	17.0%	16.7%
040	9.5%	12.8%	16.0%	17.6%	11.5%
041	17.0%	16.3%	16.6%	16.3%	16.9%
042	14.5%	19.1%	17.9%	19.1%	18.2%

Table 6. (Continued)					
Panel #	**Member A**	**Member B**	**Member C**	**Member D**	**Member E**
043	14.4%	15.9%	14.5%	17.1%	15.4%
044	17.6%	17.8%	17.8%	18.3%	18.9%
045	17.6%	16.8%	18.6%	17.9%	17.4%
046	16.8%	17.9%	15.9%	13.0%	13.6%
047	12.6%	18.2%	17.1%	17.5%	18.1%
048	11.6%	17.2%	16.6%	17.9%	12.6%
049	19.6%	18.1%	16.9%	17.0%	14.9%
050	18.4%	16.3%	17.0%	13.0%	18.1%

Table 7. Nail Pullout Test Results for the Sheather Plus (Ring Shank) Nail: Outside the High Velocity Hurricane Zone (Plywood: 1/2" thick; Nailing schedule: int.: 12"O.C. Ext.: 6" O.C.)					
Panel #	**A**	**B**	**C**	**D**	**E**
001			596.11		
002				112.35	
003				71.51	
004			370.86		
005				41.13	
006				467.48	
007				485.53	
008		38.41			
009			439.41		
010				543.73	
011				263.87	
012		411.36			
013		344.57			
014				263.35	
015			367.56		
016		428.62			
017		359.81			
018				589.31	
019				459.89	
020			499.56		
021		563			
022			428.96		
023				390.54	
024		465.28			
025		222.36			
026				634.09	
027		116.57			
028				49.3	
029			60.82		
030				398.46	

Table 7. (Continued)					
Panel #	**A**	**B**	**C**	**D**	**E**
031			404.18		
032				350.48	
033				19.61	
034			100.68		
035			447.4		
036				386.12	
037			68.54		
038			83.85		
039			487.16		
040				667.11	
041			442.77		
042				333.83	
043				392.26	
044		357.26			
045			536.73		
046		253.62			
047				281.45	
048				408.21	
049		623.02			
050				471.2	

3.2.c COMPARATIVE COST-ANALYSIS FOR VARIOUS ROOF-SHEATHING FASTENERS

The IHRC team completed a cost comparison for replacing the 8d CB nail with the 8d RS nail for the ½" plywood roof-sheathing panels in counties outside the High Velocity Hurricane Zone in Florida.

The basis for the cost comparison was the study completed in 2003 to support the submission of the proposed modification to the Florida Building Code. The study showed that with everything else being equal, meaning mainly using the same nailing schedule, the additional cost resulting from the substitution of nails would be due strictly to the cost of materials, in this case the nails themselves.

The 2003 cost-analysis showed the increase in the cost of materials resulting from substituting CB nails with RS nails would be approximately $0.38 per roofing square or $11.40 [ELEVEN DOLLARS AND FORTY CENTS] for a house with 3,000 square feet of roofing surface using a nailing schedule of 6" o.c. throughout [meaning, both for the end and field conditions].

Since the nailing schedule outside the High Velocity Hurricane Zone calls for 8d CB nails at 6" o.c. at the edges and 12" o.c. in the field when using ½" plywood, this means a total of 33 nails would be used for each roof panel (4'x8') instead of the 45 for panels incorporated in the 2003 cost study. This represents 26.7% fewer nails.

A reduction of 26.7% in the quantity of materials [nails] represents a cost of $0.29 per roofing square instead of the $0.38/square derived from the 2003 study. A house with a 3,000 square-foot roof would see a cost increase in the order of $8.70 for the total house by using the ring shank nails. This cost increase must be compared to the 29.7% improvement if performance as measured by the added uplift capacity of the roof.

As with the year 2003 study it is important to note there could be a slight improvement in the efficiency of labor [for the roofing crew] as a result of more of the 8d RS nails being loaded in the nail gun than when using the 8d CB nails.

This cost analysis would need to be reassessed in the event the nailing schedule is changed from a 6"/12" o.c. to a uniform 6" o.c., as there would be an increase in the cost of labor resulting from the 36.3% larger quantity of nails to be driven. This new assessment of cost implies the need for a task and movement analysis to see how much more time would be required to drive the additional nails using power tools.

3.2.d RESEARCH AND DEVELOPMENT OF MODIFIED-DESIGN FOR DRIP-EDGE FLASHING

This research topic continues in its conceptual theoretical stage. The key hypothesis is that the drip-edge flashing that is installed around the perimeter edge of a roof, could play a significant and cost-effective role in reducing the potential for damage to a roof under hurricane impact, if its basic shape is modified in order to make it perform as a type of wind spoiler at the edge of the roof. It is assumed that such a spoiler would influence the interaction of the wind-field with the roof, as a result it is hoped that some of the initial damage to the roof covering may be reduced, thus reducing damage to other components of the roof.

Given the low cost of the materials and installation involved the expectation is that any reduction in the potential for damage from hurricane impact could be achieved at positive benefit-to-cost ratio.

Carrying this research out involves a combination of reduced-scale model testing and the loading of full-scale mock-ups using the Wall-of-Wind (WOW) apparatus. Once the first WOW apparatus is delivered to the IHRC team this specific research topic can be tackled during the 2004-2005 HLMP research period.

3.2.e RESEARCH AND DEVELOPMENT INTO THE EFFECTIVENESS OF ROOF-EDGE SPOILERS

This area of research is complementary to the one above [Drip-edge roof flashing] and it is based on the same hypothesis that the potential for roof damage, from the impact of hurricanes, can be reduced to the degree that we are able to modify the interaction of roof with wind through the installation of various devices [*spoilers*].

The IHRC team plans to concentrate this type of research on spoilers that would be installed on the gable-end roof-edge, as this has proven to be one of the most vulnerable areas of a roof. However, other areas of a roof would also be explored.

Carrying this research out involves a combination of reduced-scale model testing and the loading of full-scale mock-ups using the WOW apparatus.

This topic of research remained in the hypothetical/theoretical phase pending the deployment of the reduced-scale WOW, and the full scale WOW that has been previously described.

3.2.f ASSESS THE PERFORMANCE OF VARIOUS OF VARIOUS TYPES OF ROOF COVERING

During the 2003-2004 HLMP grant period the IHRC team commenced research to assess the performance of clay roofing tiles under hurricane winds.

Empirical data has shown that roofing tiles, together with other roof-covering materials, are one of the main sources of flying debris in residential areas and other urban zones during hurricanes. In this regard roofing tiles are evidence of damage to the roof of a given house, but they also represent one of the main sources of damage to neighboring houses.

Main Objectives of this Research

This research is aimed at the following:

a) Determining how damage to a roof is caused where the covering consists of clay tile. In other words, what is the sequence of events that may lead to individual roof tiles being damaged or dislodged? Once individual tiles are damaged at what point do they become airborne as flying debris? What is the threshold of wind speed at which individual tiles can be dislodged from the roof and become flying debris?

b) What is the role of tile design [*shape, dimensions, proportions, weight etc.*] as a factor in such causality of damage?

c) What is the role of tile-installation methodology as a factor in such causality of damage?

d) What are the characteristics of flight of clay roofing tiles once they are dislodged and become flying debris? How are such flight characteristics influenced by the shape, dimensions, proportion and weight of specific ties?

e) How does the flight-speed of flying debris tiles relate to the maximum sustained winds of a hurricane specific to a given site? In other words, what is the ration of roofing tile flying speed to the wind speed of the hurricane at the site?

f) What is the force of the impact of flying-debris tile? What factors influence said force of impact?

g) Can damage to clay-tile roofs, and the incidence of clay tiles as a component of flying debris, be reduced by changing the method of installation or the design characteristics of individual clay tiles? What specific changes could lead to such reduction in damage?

Methodology

The IHRC plans to use a mix of various methods to conduct this research. These methods may include the following:

a) Testing of full-scale mock-ups of clay tile roofs using various sources to artificially generate hurricane-strength wind such as: *i)* the WOW apparatus, *ii)* the FIU open-air *roofing wind tunnel* with or without the *rain-generator* device, *iii)* a combination of airboats, as the source of simulated hurricane winds, and various devices such as contraction cones or the rain generator.

b) Using high-speed digital video, through an array of digital cameras, and other devices to record the behavior of clay-tile roofing under the impact of hurricane winds, and to document the cause of damage.

c) Using video-editing techniques to capture key data relative to the threshold for individual tile dislodgement, flight path and characteristics, ratio of tile flying speed to the speed of the hurricane wind.

d) Using those data to develop a mathematical model to forecast the characteristics of flying-debris tiles. This will establish a sound scientific foundation to this type of work.

e) Development of computer animations to illustrate the patterns of performance of clay-tile roofs under hurricane winds. This method allows for the manipulation of several factors, such as the speed at which one sees occurring events as well as the distance. Researchers can view details from a distance or in close-up and at normal speed or in slow-motion. This level of detail is impossible during real events.

Work Completed during the 2004-2004 HLMP Grant Period

Several tasks were completed during the grant period. These included the following:

a) Design and construction of a controlled test area for the testing of full-scale clay-tile roof mock-ups under simulated hurricane winds. These experiments included several components as follows:

i) A source of wind consisting of an airboat capable of generating sustained winds of up to approximately 75 mph.

ii) An array of three digital-video cameras to record the flight path and flight characteristics of individual clay roofing tiles as they were dislodged by the wind.

iii) A frame to hold the full-size roof test specimen.

iv) An open field between the test frame holding the roof test specimen and a backdrop to stop flying-debris tiles from traveling beyond a distance of 15 ft from the test specimen frame. This open field was painted with a 5' x 5' grid to help in measuring distance traveled and speed.

b) Analysis of data from the testing of full-scale clay-tile roof captured by way of digital video.

This analysis was based on the three-camera array and the painted grid on the open field in conjunction with the rpm/wind speed of the airboat propeller used as the source of wind.

The three-camera array provided a three dimensional set of coordinates that was useful in defining the path and characteristics of flight for dislodged tiles that became airborne. This process also involved the slowing down of the digital video that recorded each test in order to determine distance traveled and flying speed for each tile.

This analysis allowed the IHRC team to record the speed of flying tiles as a percentage of the speed of the wind generated by the airboat propeller used as the source of wind. Based on the preliminary analysis of these data the IHRC team was able to reach some initial conclusions, including the following:

i) Barrel-shaped clay roofing tiles once they have been damaged or have become dislodged by impact [i.e. such as from flying debris] will become airborne under winds as low as 50 mph provided they are not attached a rood according to building code specifications.

ii) Once airborne these tiles will follow a flight path that is normal to the general direction of the propelling winds.

iii) Once airborne this type of tile will tumble along its long axis, which orients itself parallel to the general direction of the propelling winds.

iv) The speed of the flying tile is proportional to the maximum sustained speed of the propelling winds. Also the ratio of flying tile speed to the speed of the propelling winds will increase as the propelling wind gets stronger. Preliminary data analysis would appear to indicate the ratio of flying tile speed to the speed of the propelling winds is in the order of 35% to 40% for minimal hurricane winds. Intuitively this ration might increase to 45%-50% for higher category hurricanes or even beyond that. While this is still subject to a lot more testing and data analysis, it would mean that tiles could fly at speeds of 25 mph to 30 mph under category 1 hurricanes and exceed 50 mph or even 60 mph during category 3 hurricanes.

v) More testing is required in order to precisely determine the ratio of flying tile speed to propelling wind speed across a range of maximum sustained speeds for the source of wind. These data will be critical in determining the force of impact of flying tiles for various categories of hurricanes. Such continued testing will become possible with the addition of the WOW apparatus.

c) Design and construction of a controlled test area for the testing of full-scale specimens to study the ratio of the flying tile speed to that of the hurricane wind field.

This controlled test area was laid out on an open field north of the FIU Engineering Center at the Flagler and NW 107th Avenue campus in Miami. The layout was similar to that described in the previous sections except for the camera-array and the fact that a compressed air cannon was used to propel the individual tiles toward a frame holding a target consisting of a sheet of 5/8" CDX plywood over a 2' x 4' opening [simulating a window opening].

Each test involved careful recording of the air pressure used for each shot and of the actual speed of the flying tile right before impact as captured by a radar beam. Results can be found in Table 1.

Each repetition was recorded using high-speed digital video.

Preliminary analysis of data from these tests has shown a barrel-shaped clay tile can go through a sheet of 5/8" plywood when it reaches speeds in excess of 55 mph, or at somewhat lower speeds if the plywood has sustained previous damage from the impact of flying debris.

Again, as it has been stated before, additional testing and careful recording and analysis of test data will be needed before more definite findings are achieved.

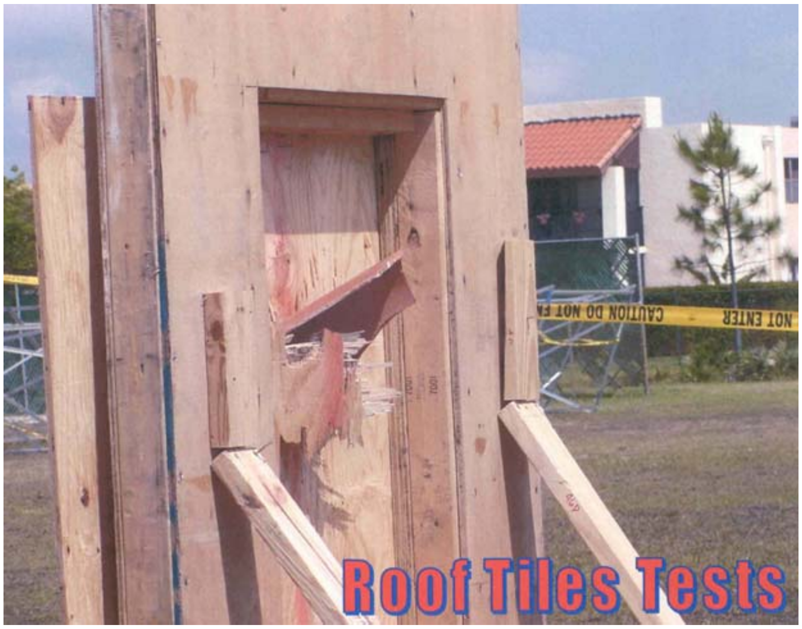

Table 1. Tile Impact Testing Results Using Air Cannons (Tile Weight 6.15 lb.)				
Test Number	**Distance From End of Barrel to Target**	**Pressure (psi)**	**Speed (mph)**	**Drop (inches)**
1 (5/8" plywood)	15	8	32.3	16
2 (5/8" plywood)	15	9	31.1	8
3 (5/8" plywood)	15	10	36	8
4 (5/8" plywood)	15	11	38.3	12
5 (5/8" plywood)	15	12	39.7	16
6 (5/8" plywood)	15	13	42.1	10
7 (5/8" plywood)	15	14	45.2	10
8 (5/8" plywood)	15	15	45.8	11
9 (5/8" plywood)	15	16	46.9	14
10 (5/8" plywood)	15	17	47.5	10
11 (5/8" plywood)	15	18	48.6	11
12 (5/8" plywood)	15	20	51.8	4
13 (5/8" plywood)	15	22	56.1	8
14 (1/2" plywood)	15	24	60.7	7
15 (1/2" plywood)	15	26	66.6	5
16 (1/2" plywood)	15	28	57.7	8
17 (1/2" plywood)	15	30	73.6	0
18 (1/2" plywood)	15	35	63.2	2
19 (1/2" plywood)	15	40	55.7	0

d) Development of a computer-animated digital video showing the performance of a tile roof under the impact of hurricane winds.

Data captured by the three-camera array served as a foundation for the development of an animated video depicting the sequence of events from the time a tile is dislodged and becomes airborne, while it flies and tumbles through the air until it hits another house or object interfering with its flight path. This animation was developed by FAU [Florida Atlantic University] Center for Electronic Communication under the supervision of Dr. Edmund Skellings, and professors Fran McAfee and Vivek Patel interacting with Ricardo A. Alvarez from FIU.

The resulting animated video was shown by Alvarez and Mcafee during workshops chaired by Alvarez at the 2004 Governor's Hurricane Conference, in Tampa, Fl, and the 10th Annual South Florida Hurricane Conference, in Ft. Lauderdale, Fl.

Based on initial results the IHRC team has found the animated video serves as a complement to actual research, and it also serves as an essential tool for efforts of education and outreach to share the findings from HLMP funded research.

3.2.g RESEARCH OF PERFORMANCE IMPROVEMENT OF EXISTING ROOFS BUILT PRIOR TO THE CURRENT APPLICABLE BUILDING CODE THROUGH VARIOUS RETROFIT MEASURES

The IHRC team conducted some preliminary testing to assess how much the performance of roof sheathing under hurricane winds could be improved by retrofitting existing roofs.

Testing conducted toward this objective focused on roofs built after 1994 using 5/8" plywood sheathing and a nailing schedule consisting of 8d common bright [smooth-shank] nails at 6" on center. The supporting structure consisted of 2"x4" SYP rafters at 2'-0" on center.

Two specific retrofit programs were assessed, as follows:

a) <u>Retrofit Program 1:</u>

Under the 6" o.c. nailing schedule it takes nine [9] nails to attach the 5/8" plywood sheathing to each of the 2"x4" supporting rafters. This specific retrofit consist of adding five 8d ring-shank nails for a total of fourteen [14] in each row. These additional nails were nailed at 3/8" o.c. from nails number 1, 3, 5, 7 and 9.

A total of fifty [30] full-size panels were tested using the FIU vacuum chamber as has been already described in detail before. Total applied pressure, until failure occurred, ranged from a minimum of 200.6 psf to a maximum of 382.8 psf with this mixed 8d CB/8d RS schedule. The average applied pressure was 239.9 psf.

When this average applied pressure of 239.9 psf is compared with the baseline applied pressure of 127 psf, one can see that an 88.9% improvement in performance was obtained. This is certainly a significant finding that warrants additional assessment to determine the feasibility of making it the standard for retrofitting existing roofs.

b) Retrofit Program 2:

This second retrofit program is a variation of Program 1 described above. This program involves adding three 8d ring-shank nails to the nine existing 8d CB [smooth-shank] nails.

The three 8d ring-shank nails were added at 3/8” o.c. from nails numbers 1, 5 and 9. The end result was a total of twelve [12] nails in each row.

A total of fifty [30] full-size panels were tested using the FIU vacuum chamber as has been already described in detail before. Total applied pressure, until failure occurred, ranged from a minimum of 154.6 psf to a maximum of 320.7 psf with this mixed 8d CB/8d RS schedule. The average applied pressure was 218.5 psf.

When this average applied pressure of 218.5 psf is compared with the baseline applied pressure of 127 psf, one can see that an 71.7% improvement in performance was obtained. This is certainly a significant finding that warrants additional assessment to determine the feasibility of making it the standard for retrofitting existing roofs.

Pressure results from the retrofitting studies are located in Tables 1 and 2.

Table 1. Pressure Test Results for the 18” Retrofitting Study ***(Nailing Schedule: common bright: int 6”o.c., 6” o.c.; Retrofit Schedule: sheather plus int: 1,5,9 ext 1,5,9)***			
Panel #	**Initial Pressure**	**Final Pressure**	**Applied Pressure**
001-R18	-2.7	-292	289.3
002-R18	-2.6	-268.7	266.1
003-R18	-2.6	-318.5	315.9
004-R18	-4	-242.2	238.2
005-R18	-3.3	-300.9	297.6
006-R18	-3.1	-306.4	303.3
007-R18	-2.1	-262.4	260.3
008-R18	-3.6	-293.9	290.3
009-R18	-3.5	-287.4	283.9
010-R18	-3.3	-265.5	262.2
011-R18	-2	-234.6	232.6
012-R18	-1.8	-210.5	208.7
013-R18	0	-296.5	296.5
014-R18	0.3	-241.5	241.8
015-R18	0.1	-221.1	221.2
016-R18	-2.4	-263.5	261.1
017-R18	-1.2	-281.4	280.2
018-R18	2.7	-287.5	290.2
019-R18	-2.4	-323.1	320.7
020-R18	-1.4	-273.2	271.8
021-R18	-4.9	-296.9	292
022-R18	-5.1	-235.7	230.6
023-R18	-4	-213.3	209.3
024-R18	-3.9	-199.6	195.7
025-R18	-4.2	-200.4	196.2
026-R18	3.4	-196.1	199.5
027-R18	-4.7	-159.3	154.6
028-R18	4.9	-168.2	173.1
029-R18	4.6	-176.8	181.4
030-R18	5	-180.5	185.5

Table 2. Pressure Test Results for the 12" Retrofitting Study ***(Nailing Schedule: common bright: int 6"o.c., 6" o.c.; Retrofit Schedule: sheather plus int: 1,3,5,7,9 ext 1,3,5,7,9)***			
Panel #	**Initial Pressure**	**Final Pressure**	**Applied Pressure**
001-R12	5.4	-347.6	353 psf
002-R12	5.5	-298.8	304.3 psf
003-R12	5.9	-225.4	231.3 psf
004-R12	5.3	-207.4	212.7 psf
005-R12	6.8	-284.2	291 psf
006-R12	6.6	-211.4	218 psf
007-R12	5	-313	318 psf
008-R12	3.4	-236.2	239.6 psf
009-R12	3.5	-357.4	360.9 psf
010-R12	3.6	-237.1	240.7 psf
011-R12	5	-299.4	304.4 psf
012-R12	-4	-270.6	266.6 psf
013-R12	-4.6	-299.1	294.5 psf
014-R12	-3.5	-255.4	251.9 psf
015-R12	-3.7	-304.1	300.4 psf
016-R12	-0.5	-306.9	306.4 psf
017-R12	0	-200.6	200.6 psf
018-R12	0.1	-280.7	280.8 psf
019-R12	1.1	-310.6	311.7 psf
020-R12	0	-285.1	285.1 psf
021-R12	4.7	-255.8	260.5 psf
022-R12	4	-311.8	315.8 psf
023-R12	4.2	-340.8	345 psf
024-R12	4.1	-316.1	320.2 psf
025-R12	3.4	-379.4	382.8 psf
026-R12	2.6	-371.9	332.3 psf
027-R12	4.8	-330	334.8 psf
028-R12	4.4	-327.9	332.3 psf
029-R12	4.3	-325.6	329.9 psf
030-R12	4.8	-251.7	256.5 psf

3.2.h BENEFIT-COST ANALYSIS FOR VARIOUS PERFORMANCE MODIFIERS

No additional benefit-cost analysis, other than described above, were completed during the 2004-2004 period.

The IHRC team expects that as the design and development of additional performance modifiers progresses through research to be conducted in the future, pertinent cost-analysis will also be completed. The addition of the WOW apparatus, and other equipment will contribute to these developments in the future.

3.3 DEVELOPING NEW TESTING PROTOCOL FOR IMPACT TESTING

The main objective of this research topic is to define flight and impact characteristics of roofing tiles converted into flying debris during hurricanes. This objective is based on empirical information that shows roof covering materials are one of the main components of flying debris during hurricanes. With roofing tiles being so prevalent in South Florida this type of research could provide critically important findings that may lead both to improved methods of installation for roofing tiles, and also to a new impact testing protocol that would use roofing tiles as flying debris to test the resistance of various building envelope components and other building materials to the impact of such projectiles.

The goal of the IHRC team through this research is to contribute to hurricane loss mitigation in vulnerable communities throughout Florida, but especially in the High Velocity Hurricane Zone.

Preliminary work under this research topic was commenced during the 2003-2004 research period. Most of the tests related to this research topic were described above under section 3.2.f.

This narrative is complemented by the animated video created by the Center for Electronic Communication at FAU that is being attached to this report.

3.4 IMPROVEMENTS OF “FLAT ROOF SENSOR” ATMOSPHERIC INSTRUMENTS AND DATA COLLECTION SYSTEM

Introduction

The idea that houses can be outfitted with sensors of various types in order to collect invaluable data on the performance of structural systems, and the many assemblies and components that together make the complete house, had been advanced by researchers at other academic institutions outside FIU, (i.e.: Reinhold at Clemson University, Clemson, SC; Gurley at the University of Florida, Gainsville, FL).

This research has led to the need for an independent source of data-capture to measure the strength of surface [10 meters above ground] wind fields in the vicinity of an instrumented house. Those surface wind data provide a critical reference point for data, such as wind pressure on various parts of a roof and on walls, collected by instrumentation attached to the house itself.

The IHRC team started researching this area during the 2001-2002 HLMP grant period when it funded work by FIU Department of Construction Management/College of Engineering professors Mitrani and Caballero for the design of a prototype roof sensor to be installed on flat roofs. The work continued during the 2002-2003 HLMP grant period where the IHRC team [Alvarez and Robertson] worked with FIU Hemispheric Center for Environmental Technology [HCET] researchers Ravinet and Polo, to deploy an array of sixteen [16] such flat roof sensors on a section of the College of Engineering Building.

Work on this important research continued during 2003-2004 with the collaboration of the same Alvarez/Robertson [IHRC] and Ravinet/Polo [HCET], assisted by IHRC staff member and program administrator Scott Caput.

This work was complemented by commissioning the fabrication of an “enhanced-design” self-standing wind-tower to be deployed in the open field to the northeast of the College of Engineering Building in order to provide the independent source of data capture for surface winds in the vicinity of the roof outfitted with the sixteen flat roof sensors. The enhanced design for this tower, which is based on similar deployable self-standing towers used in the HLMP funded *Florida Coastal Monitoring Program*, is the result of collaboration between Alvarez [FIU], Reinhold [Clemson] and Gurley [UF]. The tower has been fabricated and it will await deployment once a hurricane approaches the Miami area.

The above picture shows some of the flat-roof sensors deployed on the College of Engineering Building at FIU Engineering Campus, Flagler Street and NW 107th Avenue. These sensors are connected to a field point modular that is linked to a National Instrument's PXI computer running the Labview V.7 software package. The roof has also been outfitted with a directional mechanical anemometer also connected to the PXI computer.

Because this particular anemometer captures wind data influenced by the shape and size of the building itself, the addition of the open-field ten meter wind-tower will add a critical source of independent surface wind data.

Background

Windstorms cause severe structural damages to people and buildings. It has been found that losses in the United States alone reach several billion dollars; most of the losses are due to roof damage. Several studies have shown that the suction forces, resulting from the formation of vortices along the roof edges, damage flat building roofs. These suction forces represent the largest uplifting force on the roof and also are the most common failure of the roof. The worst mean and peak suctions on flat building roofs occur for cornering or oblique wind angles. At such angles, conical or delta wing vortices form along the roof edges (see Fig. 1) bringing about variation of surface pressures.

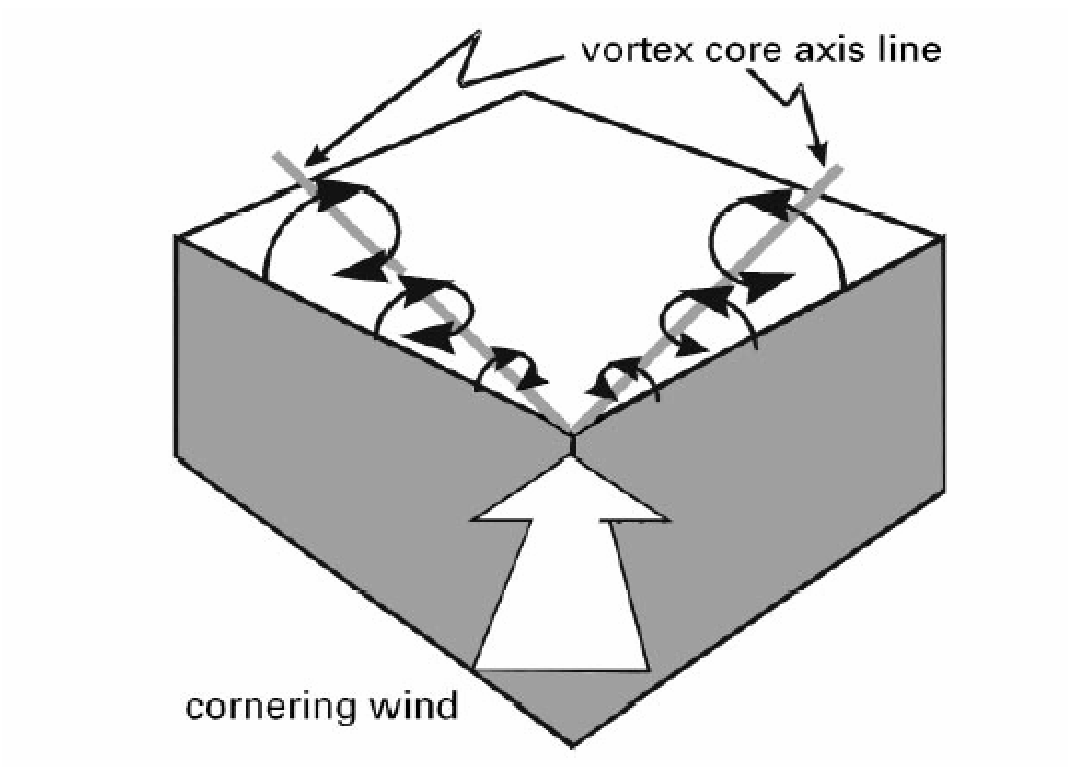

Figure 1: Conical “delta-wing” corner vortices

Letchford and Mehta found that lateral turbulence plays important role in surface pressure fluctuations, which also depend of the wind direction[2].

The Hurricane Loss Mitigation Program (HLMP) proposed a project in 2003 to develop a technology, which can monitor the effect of wind loads on the flat roof. Knowledge acquired from past research on flat roofs using wind tunnel and scale building models has led to the implementation of a program consisting of monitoring the development and behavior of high surface pressures created when a hurricane

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2 *Flow visualization of conical vortices on flat roofs with simultaneous surface pressure measurement*
D. Banks, R.N. Meroney, P.P. Sarkar, Z. Zhao, F.Wu
Journal of Wind Engineering and Industrial Aerodynamics 84 (2000) 65}85

strikes a typical flat roof commercial buildings.

This program involves a sensor package, which is designed to monitor atmospheric pressure changes and wind loads – velocity and direction - on building flat roofs. Figure 2 shows the mounted sensors with their protective housing. They were arranged following the wind vortices alignment (Vortex Core Axis Line).

Figure 2: Current arrangement of 16 Sensors

In 2004, a new sensor package was redesigned in order to enhance the previous year package covering all those parameters not considered in the previous year that could affect the behavior of flat roof under hurricane wind forces.

Objective

The main purpose of the 2004-year program is to,

- Improve the flat-roof instruments and data collection system located at the roof of the FIU Engineering Center Building.

- Widen the range of the data system by installing additional instruments including rain gauge, temperature and humidity probes, a second wind velocity and direction sensor, and some barometric sensors.

- Collect the data, which can be used in the future, to assess the structural performance of the building as it interacts with extreme winds and hurricanes.

Flat-Roof Instruments and Data Acquisition System

In the 2003-year program a total of sixteen atmospheric pressure transducers and one anemometer consisting of a RM Young wind monitor that measures the wind speed and direction, were installed on the Northwest corner of the FIU Engineering Center Building. The sensors and the wind monitor were connected to a Data Acquisition System (DAQ). This system is based on the National Instruments LabView, version 7.0. Sensors are connected to the field points, which are connected to a Virtual Instrument (VI). The data collection system is controlled by a PXI from National Instruments. The sensors measure absolute pressure and convert the reading in to a voltage output, which is transferred to the DAQ. The sensor measurement is represented on the screen using two analog indicators. Each channel represents eight sensors and can be adjusted using a push button. The rate of sampling can also be modified through a push button and is also indicated using a digital indicator[3].

During this research year, the PXI was relocated to the Robotic Lab in the Hemispheric Center for Environmental Technology (HCET) allowing controlled access to the data. Also new sensors were installed at the opposite side of the previous year's instrumentation set to enhance the collected data from the flat roof area. The new purchased instruments include, 3 barometric sensors, a rain gauge (8 inch diameter tipping rain gauge), a thermocouple (Vaisala temperature probe), a humidity sensor (Vaisala), and an anemometer along with a data logger. The layout of the sensor arrangement is shown in Figure 3:

[3] *International Hurricane Research Center, "Hurricane Loss Reduction For Housing in Florida". Final Report. June 30, 2003*

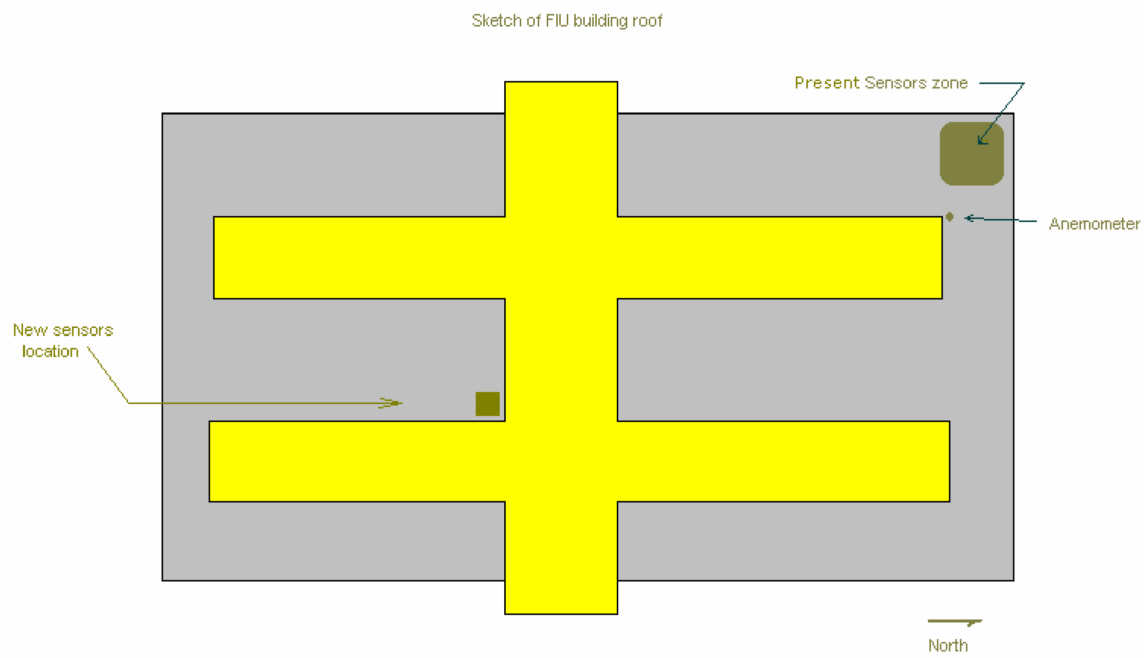


Figure 3: EC building roof layout

Improvement of the Flat-roof Instrument System Network

The initial flat-roof instrument system included sixteen barometric sensors and a wind anemometer situated along the Northwest edge of the FIU Engineering Center's flat roof. An example of the data obtained from the initial sensor network arrangement is shown in Table 1. The sensors produced erroneous output and the data from each sensor were inconsistent. It was identified that most of the sensors were not working properly and all the cables were not stably attached. This situation allowed the presence of high moisture inside the sensor housing affecting the performance of the sensors.

Table 1: Example data from some sensors and the anemometer

Time (02/25/04)	Sensor 1 (psf)	Sensor 2 (psf)	Sensor 3 (psf)	Sensor 4 (psf)	Sensor 5 (psf)	Sensor 12 (psf)	Sensor 7 (psf)	Wind Direction	Wind Speed (mph)
20:05.1	481.876	-199.792	3.436	-429.29	37.558	-586-59	-24.435	237.572	20.176
20:06.1	481.876	-199.592	3.436	-429.29	41.768	-586.59	-24.244	238.838	25.172
20:07.1	481.876	-199.993	3.436	-429.29	36.355	-586.59	-24.244	227.974	26.901
20:08.1	481.876	-199.792	3.436	-429.29	38.159	-586.59	-24.244	236.728	31.619
20:09.1	481.876	-199.592	3.436	-429.29	42.169	-586.59	-24.053	234.513	31.297
20:10.1	481.876	-199.792	3.436	-429.29	41.367	-586.59	-24.435	231.982	27.224
20:11.1	481.876	-199.993	3.436	-429.29	36.956	-586.59	-24.435	242.318	32.293
20:12.1	481.876	-199.592	3.436	-429.29	33.949	-586.59	-24.626	234.724	31.443
20:13.1	481.876	-199.993	3.436	-429.29	29.939	-586.59	-24.435	225.232	31.238

HCET researchers considered that the sensor network needed improvements and the following measures were adopted to achieve optimal results.

- Absolute pressure transducers were removed and sent to Clemson University for re-calibration purposes.
- Absolute pressure transducer housing were removed, drilled and stably attached using 6 inches long bolts and glued at the sides to prevent any possible leaking or moisture inside the dwelling. Also the aluminum housing was coated with solar reflective paint to prevent overheating of the sensors.
- Additional barometric sensors and other instruments were installed.
- A new wireless data acquisition system was purchased to connect the new sensors to the network.

Absolute pressure transducers were re-calibrated by Dr. Tim Reinhold at Clemson University and were received by HCET at the end of May 2004. Transducers were calibrated against a Setra Model 370 Digital Pressure Gauge with an operating range of 800 to 1100 milli-bars. The speed range of the propeller is set at 0 to 200 mph. The new calibration graph for each transducer is given in Appendix A. The re-calibrated transducers were connected back into the system within their housings, which were improved to assured that sensors were isolated from external agents.

Weathering secured housings arrangement, shown in Figure 4, consist of adding the following features:

– Several 6” bolts attached the base and cover of the dwelling,
– Caulking applied to the joined area of the cover and base of the house, arranged to assure a chamber space free of moisture,
– Coating to avoid overheating, and
– Metal mesh stuck to each lateral hole to keep away bugs, insects, and dust that can make nest inside the cabinet chamber and cover the sensors.

Figure 4: Sensor with a weathering secured housing

Figure 5. Sensor housing being fixed by researchers

Since the sensors are absolute pressure transducers; the offset will change depending on the atmospheric pressure. They are also somewhat sensitive to temperature changes. Consequently, a reference offset needs to be established for each event and this may change during a storm as the atmospheric pressure and ambient temperature change[4]. These reasons initiated researchers to improve the efficiency and consistency of the data by installing new sensors and other weather instruments to consider all the parameters that could affect the atmospheric pressure measurement. The new purchased instruments include, 3 barometric sensors, one 8 inches diameter-tipping rain gauge, one temperature and humidity probe, a wireless communication system, and a CR10X data logger necessary to convert sensor I/O signals to digital signals.

Because atmospheric pressure is sensitive to temperature changes, a temperature and humidity probe were added to data collection in order to establish correlation along those parameters. A rain gauge was added to the collection data to obtain an accurate account of rainfall during a storm event. Three barometric pressures were allocated on the flat roof in an opposite corner to get an average of the atmospheric pressure that could later be compared with the transducers data. Figures 6, 7, 8, and 9 show the newly installed instruments.

Figure 6: Rain Gauge

Figure 7: Thermocouple

[4] Dr. Tim Reinhold – Clemson University Researcher

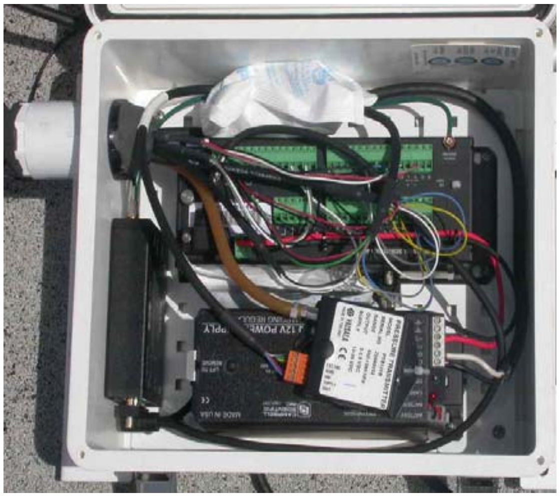


Figure 8: CR10X Data Logger

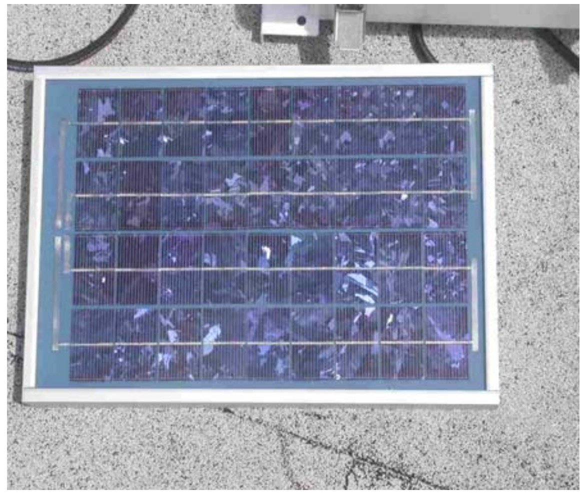


Figure 9: solar panel

The data is continuously generated from the sensors not including the transducer calibration time. Sensors have not had a chance to interact with extreme wind conditions and hurricanes. However data collected by the various sensors could be utilized later for analyzing the performance of the building as it interacts with extreme winds and hurricanes.

Conclusion

As a part of the FIU Hurricane Loss Reduction Program (HLRP), researchers have been given a task of improving the flat-roof instrumentation system located in the roof of FIU Engineering Center (EC) building. Researchers performed the following task to support this task,

- Sensors were re-calibrated and re-installed into the system.
- Sensor dwellings were secured and waterproofed more tightly by making perforations with bolts.
- New barometric sensors and other flat-roof instruments including rain gauge, thermocouple, and an anemometer were installed.
- New sensors were connected to a wireless data acquisition system.
- Data was collected continuously from the sensor network system for future analysis.

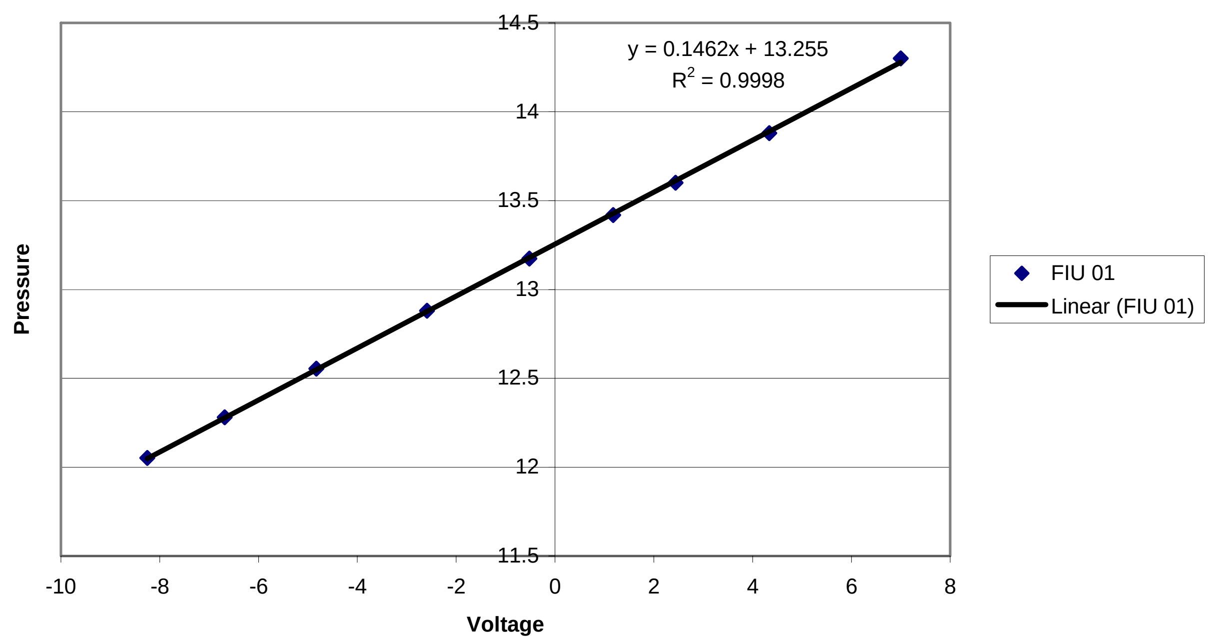
Though the objective of this program is to collect the data during extreme wind and hurricane conditions, such conditions have not been encountered during the project period. However, efforts will be made to collect and monitor the data during the coming hurricane season.

Appendix A

CALIBRATION DATA FOR FIU SENSORS June 2nd 2004

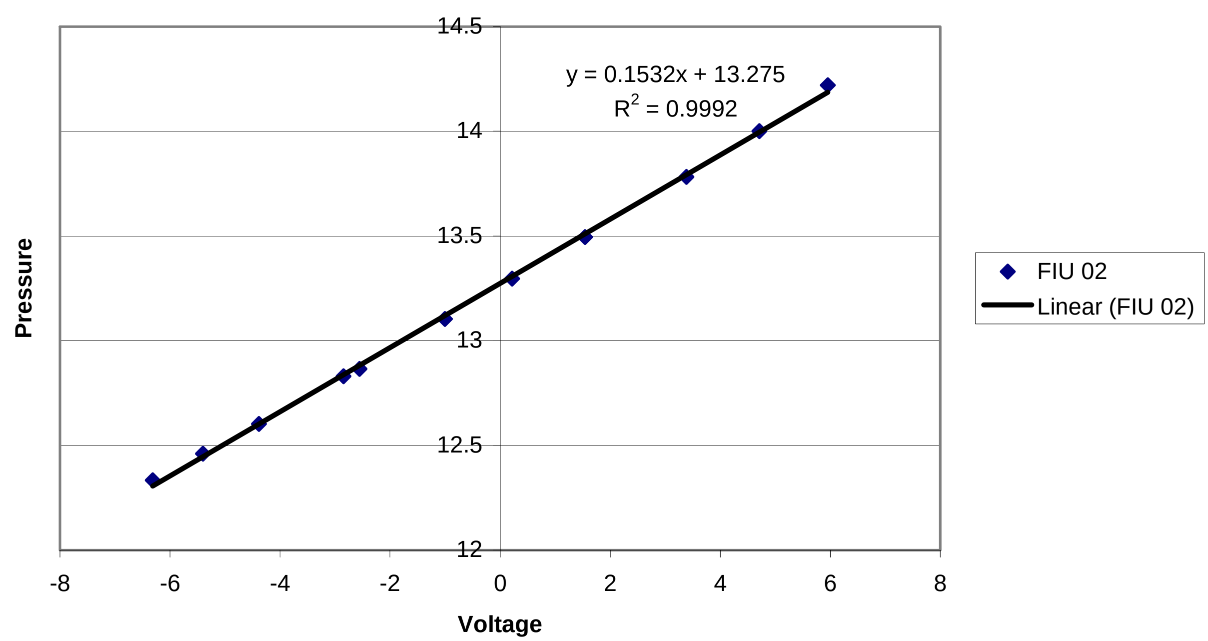
Pressure (psi)	FIU 15 (v)	FIU 05 (v)	FIU 02 (v)	FIU 09 (v)	FIU 07 (v)	FIU 06 (v)	FIU 12 (v)	FIU 16 (v)
14.0221	6.18	6.197	5.9525	6.1428	5.9673	5.4331	5.6511	6.4179
14.001	4.9369	4.949	4.7111	4.8934	4.7301	4.196	4.4138	5.1701
13.7825	3.6122	3.618	3.3879	3.5637	3.4122	2.8778	3.0956	3.8403
13.4949	1.7616	1.766	1.544	1.7091	1.5676	1.0439	1.2546	1.984
13.2969	0.4329	0.436	0.2189	0.3748	0.2421	-0.2732	-0.0676	0.653
13.1042	-0.7896	-0.787	-1.0001	-0.8498	-0.9799	-1.4882	-1.2844	-0.574
12.8654	-2.3519	-2.35	-2.555	-2.4137	-2.5411	-3.0405	-2.8371	-2.1394
12.8305	-2.6447	-2.642	-2.8456	-2.7059	-2.832	-3.3286	-3.1274	-2.431
12.6026	-4.1991	-4.187	-4.3848	-4.2502	-4.381	-4.8598	-4.6637	-3.9782
12.4612	-5.2108	-5.207	-5.4007	-5.2667	-5.4019	-5.8691	-5.6791	-4.996
12.3349	-6.1302	-6.126	-6.3166	-6.1812	-6.3236	-6.7824	-6.5927	-5.9113
	FIU 8 (v)	**FIU 14 (v)**	**FIU 04 (v)**	**FIU 11 (v)**	**FIU 13 (v)**	**FIU 10 (v)**	**FIU 01 (v)**	**FIU 03 (v)**
14.301	6.3659	5.092	5.7531	5.3065	5.4781	5.9193	6.9954	6.3574
13.88	3.7292	2.456	3.1197	2.6647	2.8549	3.2753	4.3377	3.7113
13.601	1.8465	0.0574	1.238	0.7747	0.9784	1.387	2.4399	1.8214
13.418	0.5915	-0.68	-0.0148	-0.4831	-0.271	0.1276	1.1754	0.5624
13.173	-1.0874	-2.358	-1.6923	-2.1662	-1.9423	-1.5548	-0.5163	-1.1209
12.88	-3.1454	-4.411	-3.7466	-4.2295	-3.9924	-3.6186	-2.5885	-3.1864
12.555	-5.3664	-6.631	-5.963	-6.4546	-6.2037	-5.8469	-4.8253	-5.4143
12.281	-7.2156	-8.48	-7.8114	-8.3093	-8.0473	-7.702	-6.6892	-8.2707
12.052	-8.766		-9.3615	-9.8635	-9.594	-9.2584	-8.2514	-8.8257

FIU 01



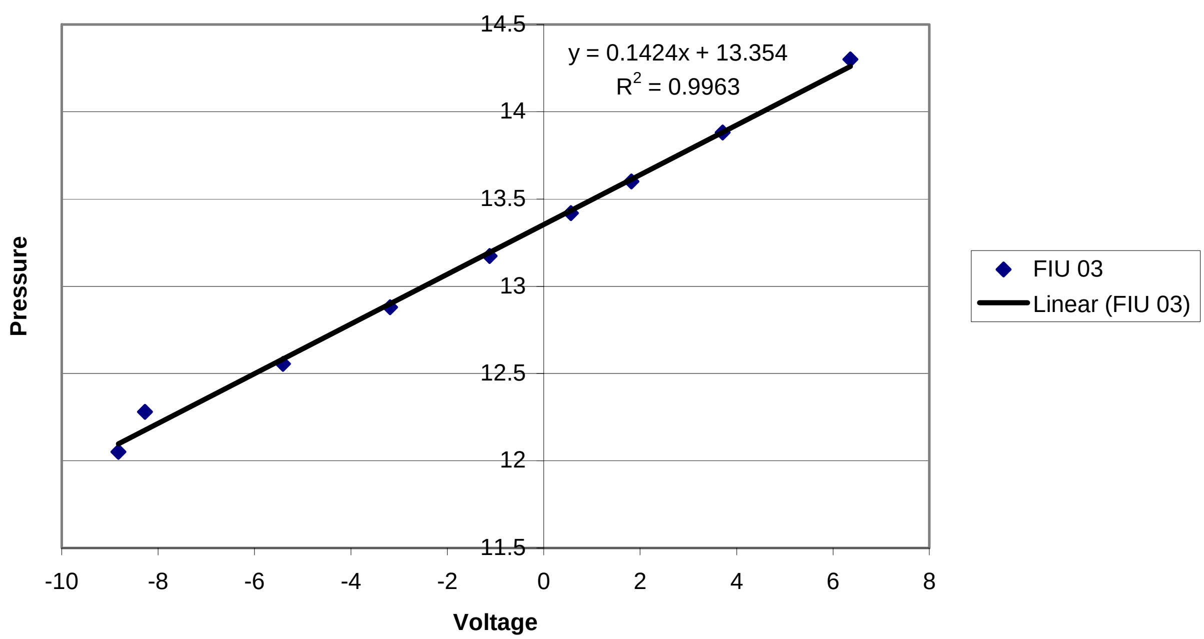
y = 0.1462x + 13.255
R2 = 0.9998
14.5
14
13.5
13
12.5
12
11.5
-10
-8
-6
-4
-2
0
2
4
6
8
Pressure
Voltage
FIU 01
Linear (FIU 01)

FIU 02



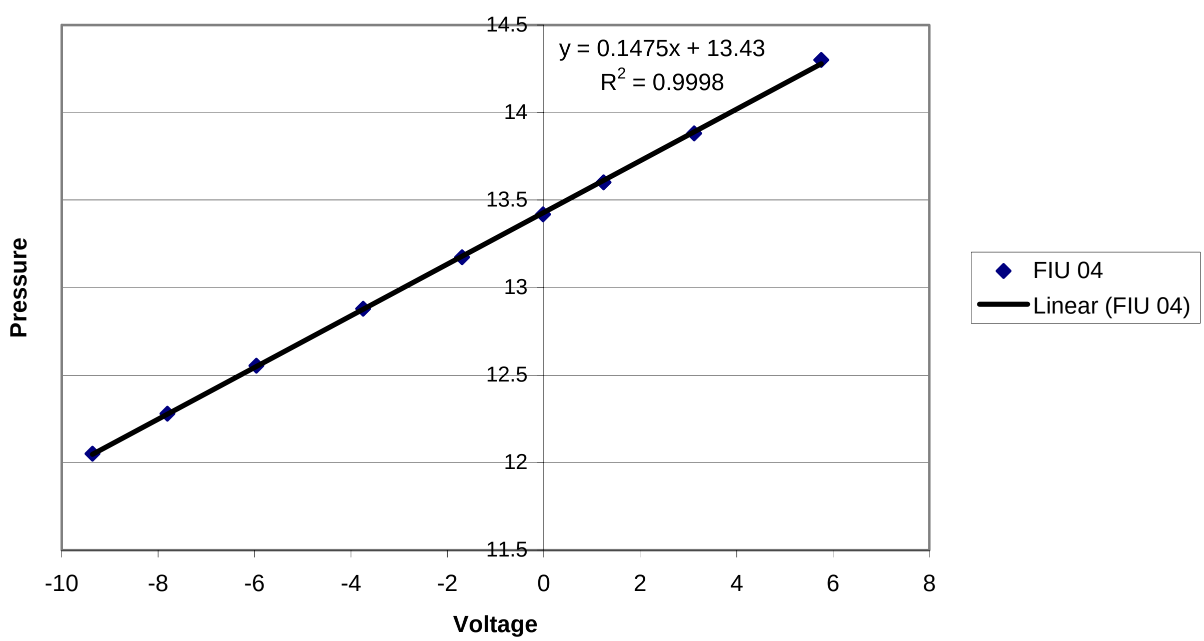
y = 0.1532x + 13.275
R2 = 0.9992
14.5
14
13.5
13
12.5
12
-8
-6
-4
-2
0
2
4
6
8
Pressure
Voltage
FIU 02
Linear (FIU 02)

FIU 03

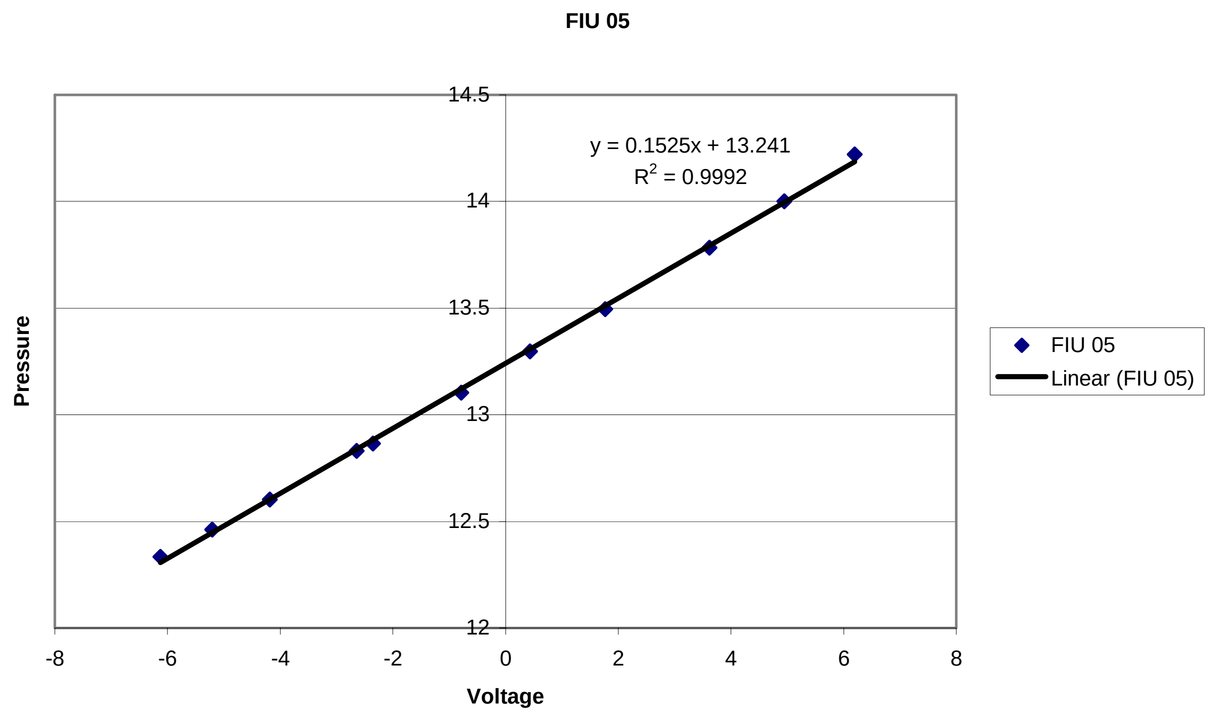


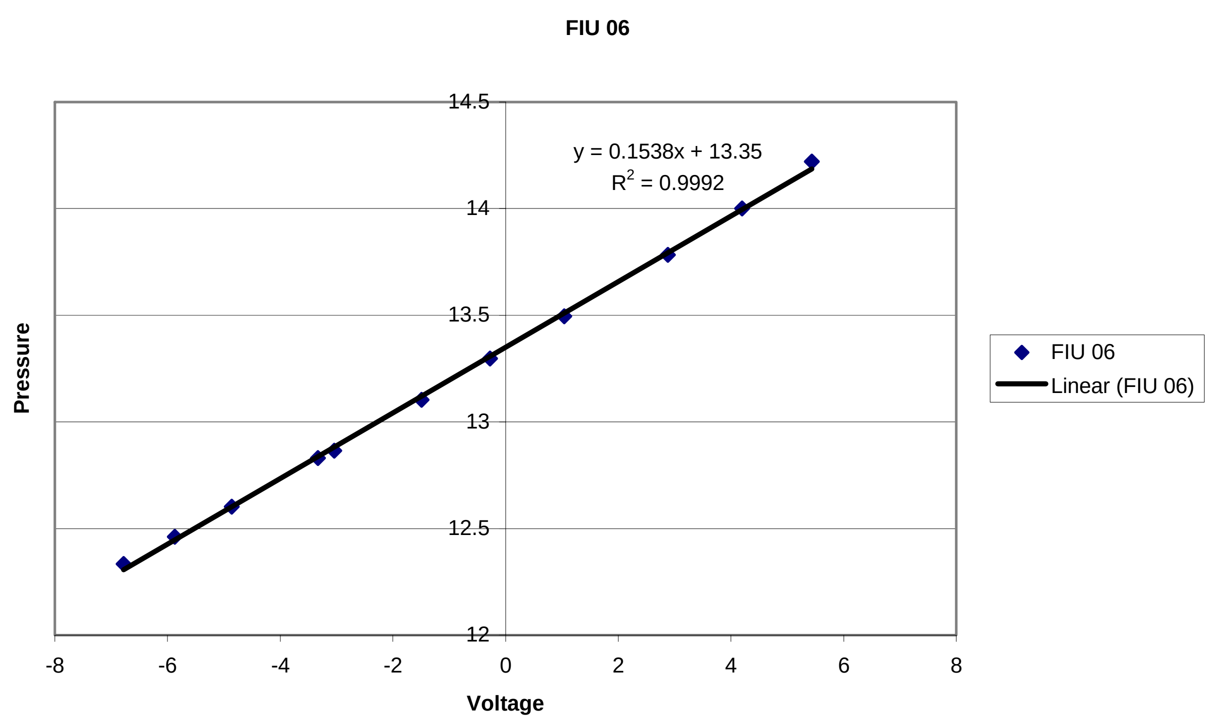
y = 0.1424x + 13.354
R^2 = 0.9963
14.5
14
13.5
13
12.5
12
11.5
-10
-8
-6
-4
-2
0
2
4
6
8
Pressure
Voltage
FIU 03
Linear (FIU 03)

FIU 04

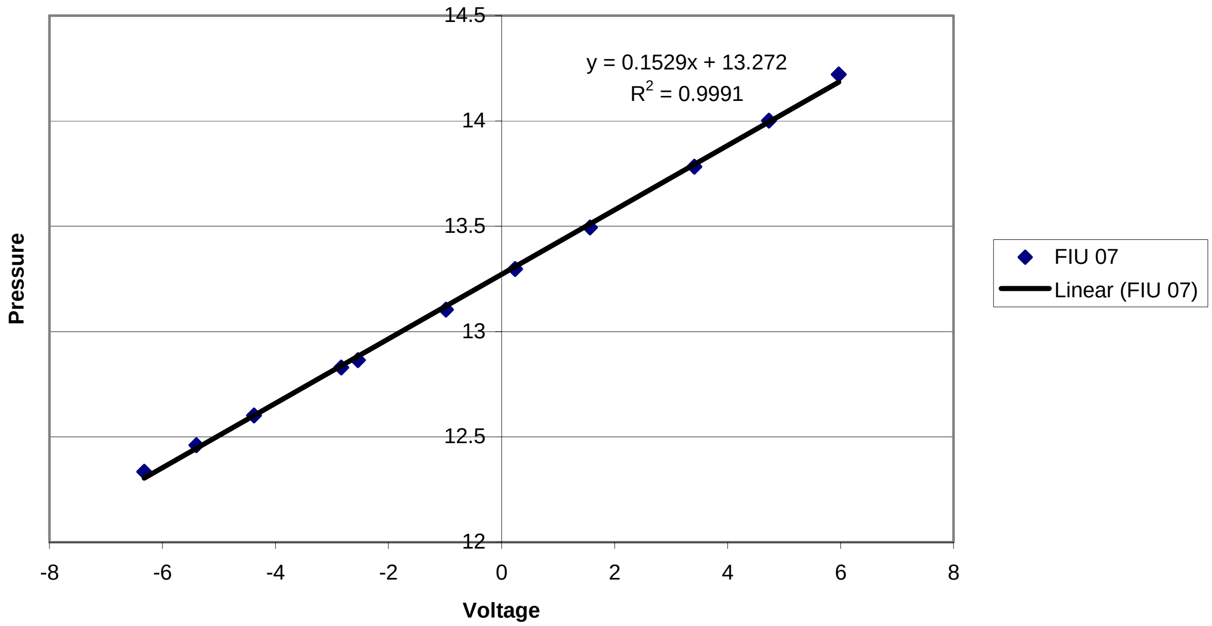


y = 0.1475x + 13.43
R^2 = 0.9998
14.5
14
13.5
13
12.5
12
11.5
-10
-8
-6
-4
-2
0
2
4
6
8
Pressure
Voltage
FIU 04
Linear (FIU 04)


FIU 05
y = 0.1525x + 13.241
R^2 = 0.9992
Pressure
Voltage
14.5
14
13.5
13
12.5
12
-8
-6
-4
-2
0
2
4
6
8
FIU 05
Linear (FIU 05)

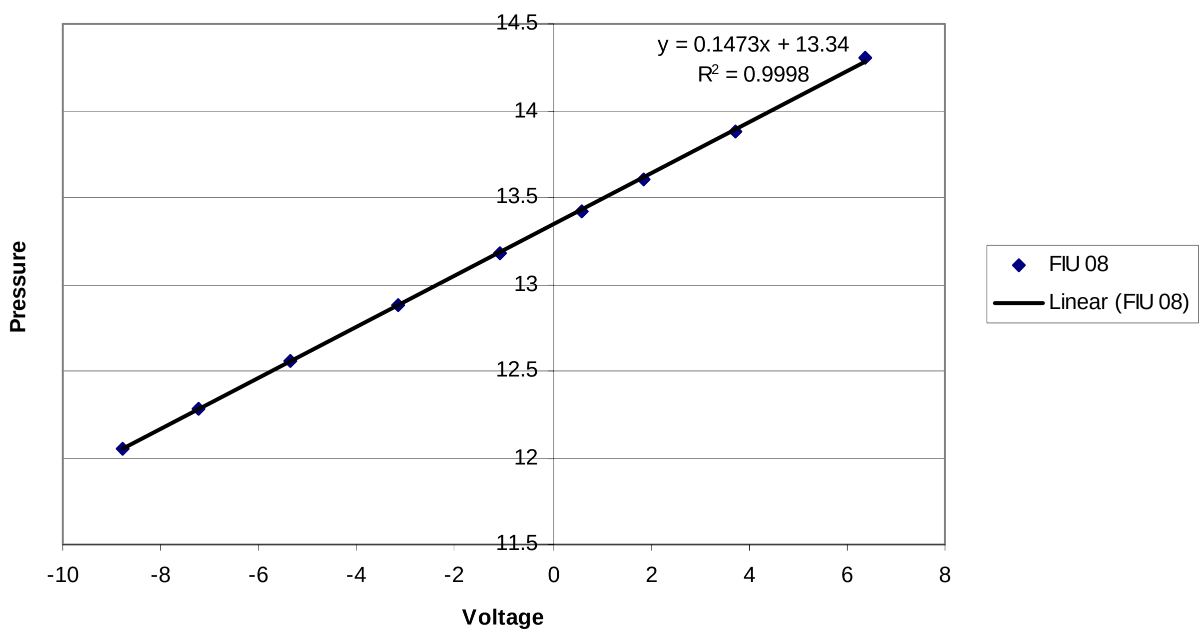

FIU 06
y = 0.1538x + 13.35
R^2 = 0.9992
Pressure
Voltage
14.5
14
13.5
13
12.5
12
-8
-6
-4
-2
0
2
4
6
8
FIU 06
Linear (FIU 06)

FIU 07



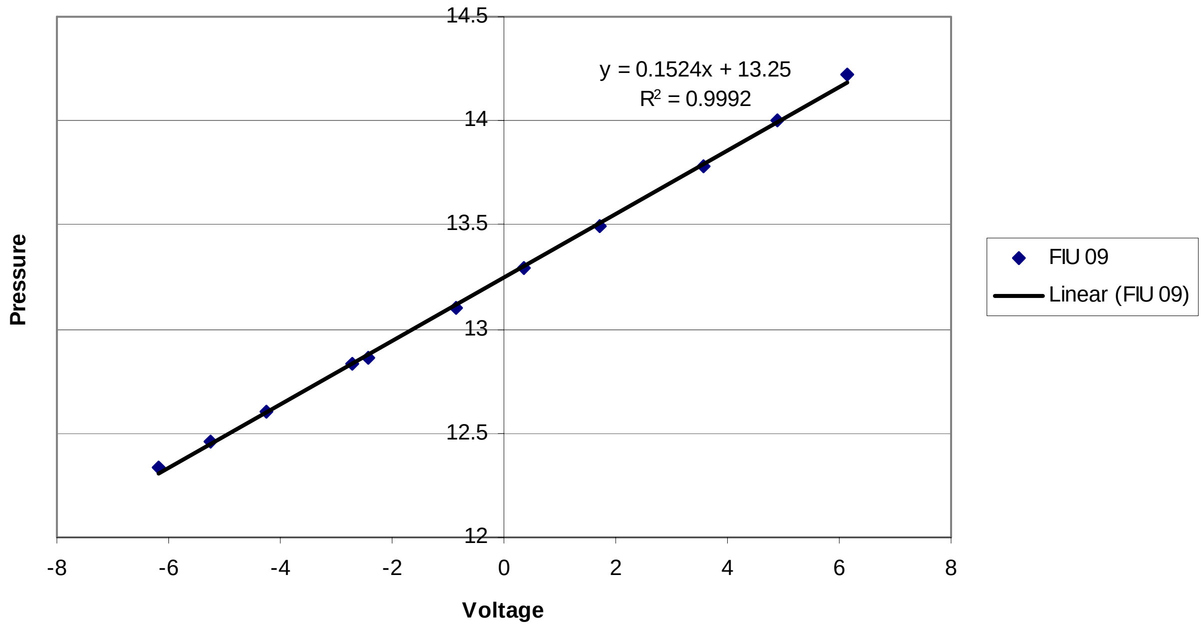
y = 0.1529x + 13.272
R^2 = 0.9991
Pressure
Voltage
14.5
14
13.5
13
12.5
12
-8
-6
-4
-2
0
2
4
6
8
FIU 07
Linear (FIU 07)

FIU 08



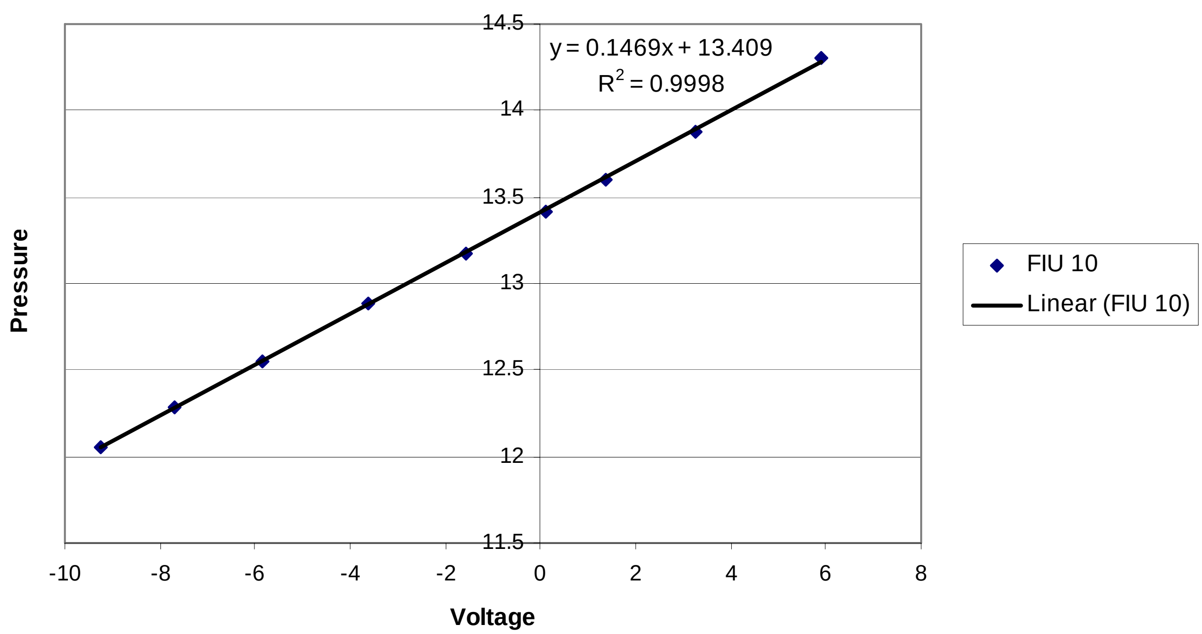
y = 0.1473x + 13.34
R^2 = 0.9998
Pressure
Voltage
14.5
14
13.5
13
12.5
12
11.5
-10
-8
-6
-4
-2
0
2
4
6
8
FIU 08
Linear (FIU 08)

FIU 09



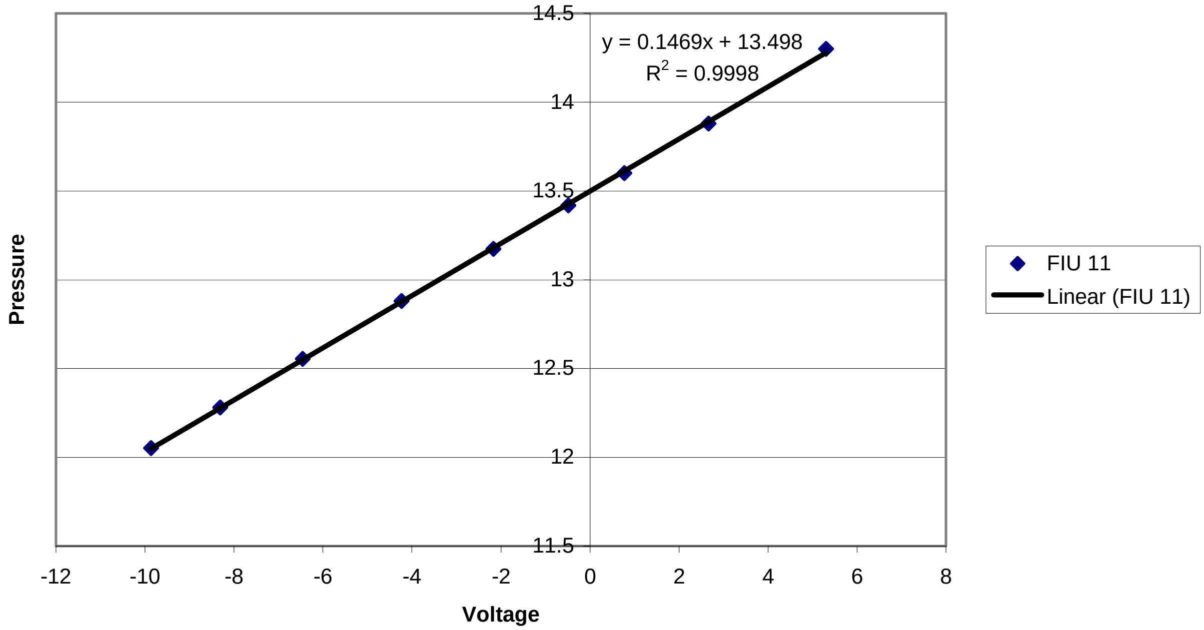
y = 0.1524x + 13.25
R2 = 0.9992
Pressure
Voltage
FIU 09
Linear (FIU 09)

FIU 10



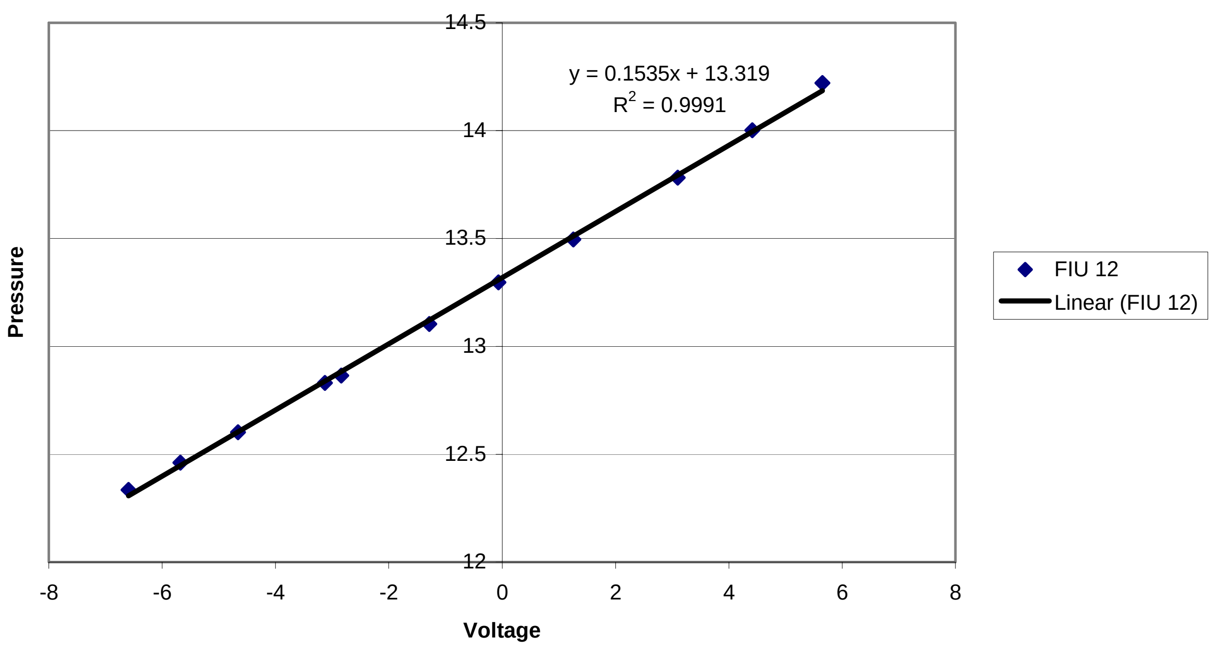
y = 0.1469x + 13.409
R2 = 0.9998
Pressure
Voltage
FIU 10
Linear (FIU 10)

FIU 11



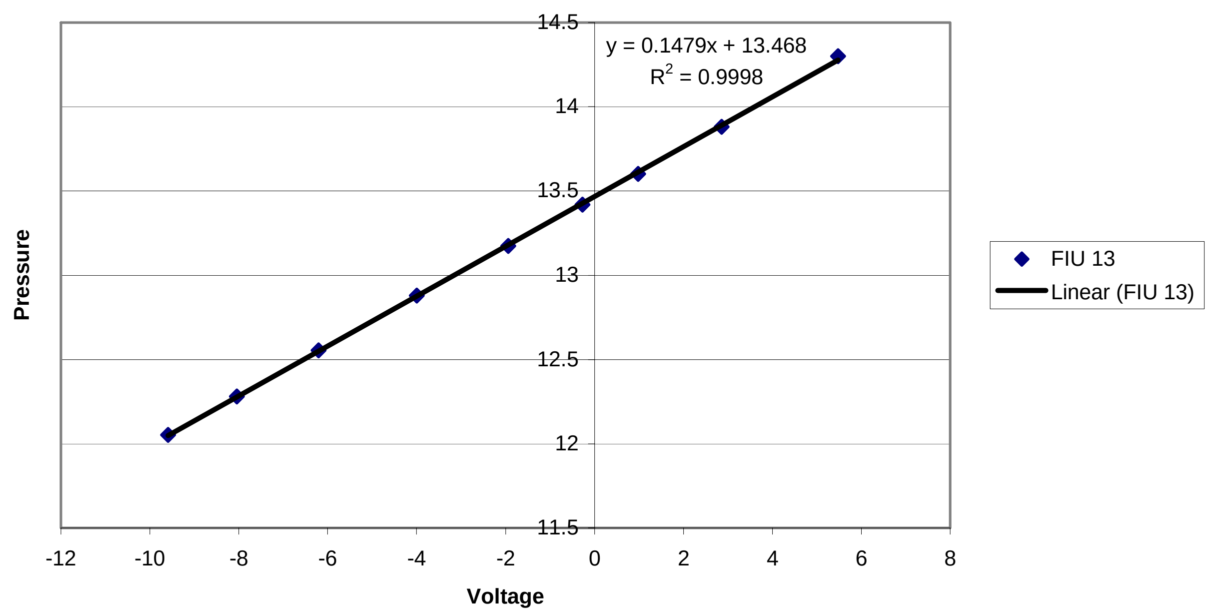
y = 0.1469x + 13.498
R^2 = 0.9998
Pressure
Voltage
FIU 11
Linear (FIU 11)
14.5
14
13.5
13
12.5
12
11.5
-12
-10
-8
-6
-4
-2
0
2
4
6
8

FIU 12

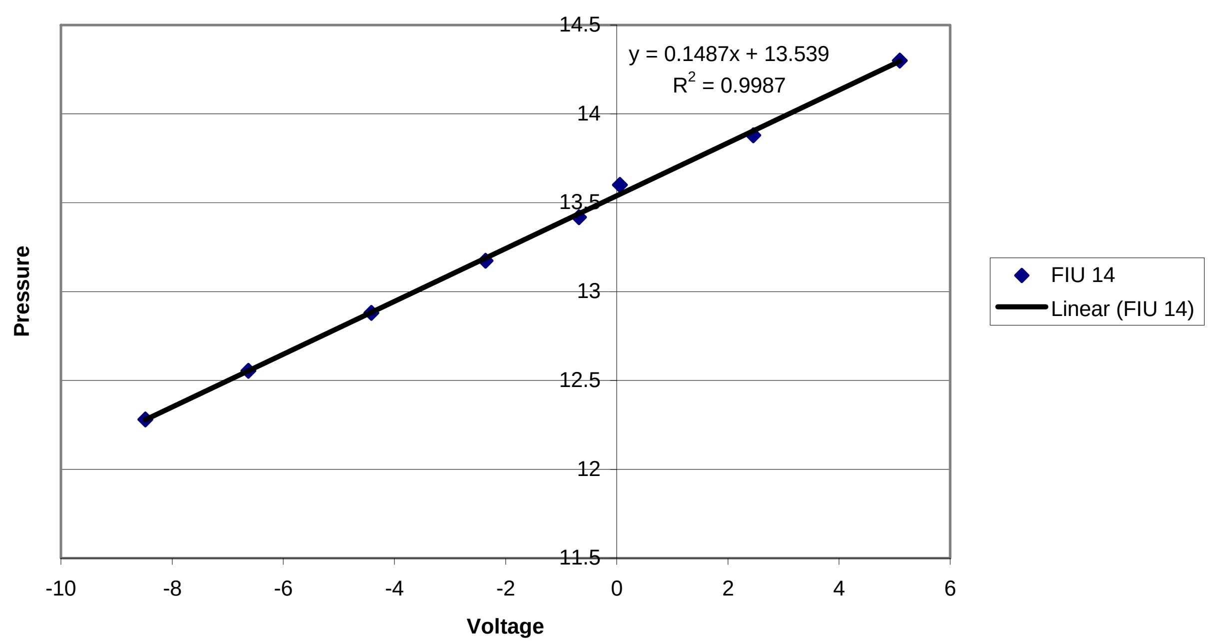


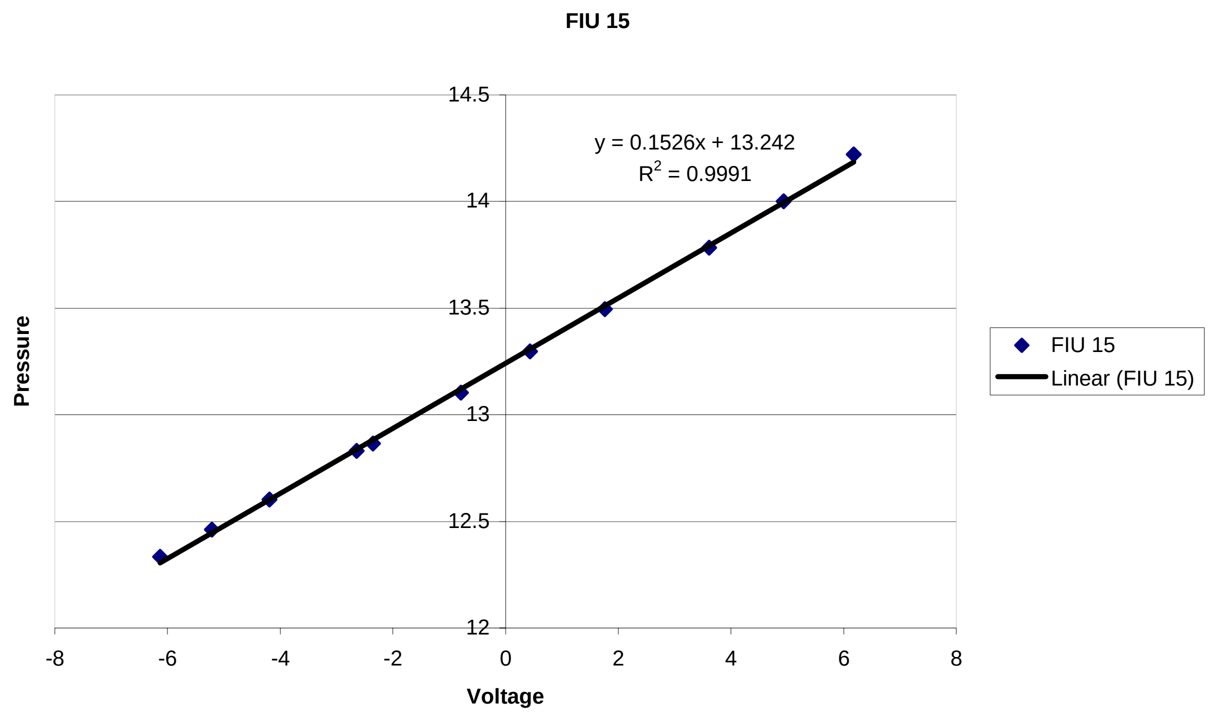
y = 0.1535x + 13.319
R^2 = 0.9991
Pressure
Voltage
FIU 12
Linear (FIU 12)
14.5
14
13.5
13
12.5
12
-8
-6
-4
-2
0
2
4
6
8

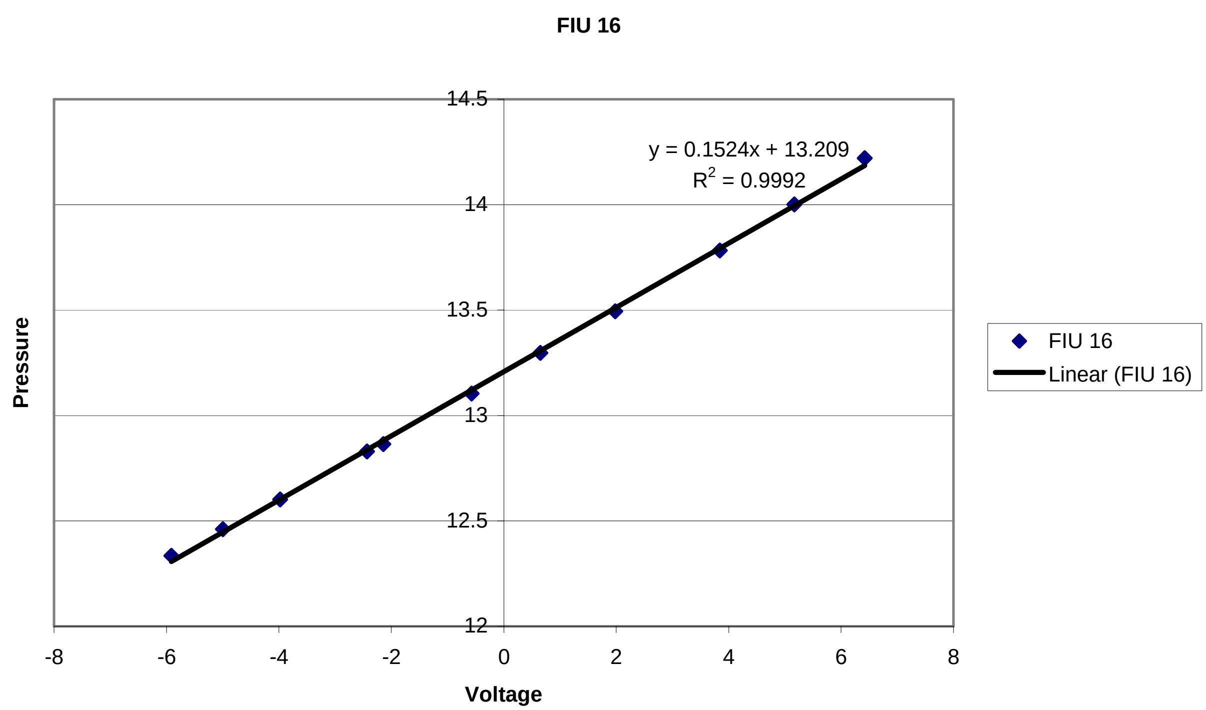
FIU 13


y = 0.1479x + 13.468
R^2 = 0.9998
Pressure
Voltage
14.5
14
13.5
13
12.5
12
11.5
-12
-10
-8
-6
-4
-2
0
2
4
6
8
FIU 13
Linear (FIU 13)

FIU 14


y = 0.1487x + 13.539
R^2 = 0.9987
Pressure
Voltage
14.5
14
13.5
13
12.5
12
11.5
-10
-8
-6
-4
-2
0
2
4
6
FIU 14
Linear (FIU 14)


FIU 15
14.5
14
13.5
13
12.5
12
-8
-6
-4
-2
0
2
4
6
8
Voltage
Pressure
y = 0.1526x + 13.242
R^2 = 0.9991
FIU 15
Linear (FIU 15)


FIU 16
14.5
14
13.5
13
12.5
12
-8
-6
-4
-2
0
2
4
6
8
Voltage
Pressure
y = 0.1524x + 13.209
R^2 = 0.9992
FIU 16
Linear (FIU 16)

3.5 STUDY OF ROOF TO WALL CONNECTIONS

Work related to the performance of roof-to-wall connections continued during 2003-2004 using the dual-load test frame owned by the Laboratory for Structural Mitigation at FIU. This work, as in past years, was conducted under the supervision of Timothy Reinhold [Clemson University] who acted as a consultant to the IHRC team.

Research during this period focused on the connection between a roof assembly and masonry walls.

Key findings from this research work include the following:

a) Tests of retrofit connections using conventional hurricane strapping attached to the masonry with double helix masonry screws provided capacities in line with the manufacturer's published values.

b) Combined uplift and shear tests produced results indicating that the capacities can be combined for these cases using the same type of vector combination found for cast in place masonry straps and the hurricane straps for light frame wood structures, conducted over the past two years.

c) Application of several cycles of loading up to the design allowable values produced load deflection curves that did not exhibit hysteresis beyond removal of the initial slack in the system. Failures for most anchors occurred in the metal strapping.

d) The H-10 style straps which included some screws near the face of the concrete did exhibit some localized failures of the concrete at load levels near the ultimate capacity of the metal strapping.

3.6 HLMP FOCUSED SURVEY: THE FLORIDA COASTAL MONITORING PROGRAM

INTRODUCTION

Each year as part of the evaluation of the effectiveness of the Hurricane Loss Reduction Program (HLMP), the Institute for Public Opinion Research (IPOR--working as an FIU subcontractor to the International Hurricane Research Center (IHRC) conducts a focused evaluation survey of a specific HLMP contracted project that is selected by DCA staff. In 2002-2003, an IPOR evaluation survey measured satisfaction with and effectiveness of newly required courses on the Florida Building Code for building professionals. In 2001-2002, its focused survey evaluated the statewide effectiveness of HLMP-funded programs that use public service announcements and training to increase public awareness and willingness of citizens to make their homes and communities safer from hurricanes. Earlier focused IPOR surveys for DCA looked at mobile home vulnerability, mitigation incentives, and windstorm insurance.

For 2003-2004, the contract selected by DCA for focused survey-based evaluation is the Florida Coastal Monitoring Program (FCMP). The FCMP designs and deploys instruments and models to understand how hurricane winds affect homes and other buildings on the ground. Previously, there had been no significant research program in place to directly measure how hurricane winds impact structures. Hurricane wind force in general in any specific location has only been estimated from high altitude aircraft and/or airborne instrument measurements. Data on how hurricane winds affect built structures had to be inferred from predictions based on wind tunnel testing of existing models, such as those incorporated in the ASCE 7-98 Standard (Minimum Design Loads for Buildings and Other Structures).

The FCMP is now providing data on hurricane winds at ground structure level and has partial instrumentation in place on built structures ready to be rapidly completed and activated to measure hurricane winds that might interact with their surfaces. Measurement of hurricane winds at ground structure level is done by mobile instrumented towers that can be rapidly moved to locations in the vicinity of where a hurricane is forecast to impact. Measurement of wind interaction and effects on building structures will be obtained from instrumented homes that obviously cannot be moved. In both cases collection of data depends on actual hurricanes being measured, so data collection is still ongoing.

FOCUSED SURVEY TASK

Following HLMP guidelines for IPOR subcontracts for focused survey evaluations, the first task was to estimate how many potential users are aware of the data and analysis produced by the project. The second task was to estimate how many prospective users found that the evaluated project's research results were useful and beneficial.

The ultimate potential beneficiaries are Florida residents whose homes may be safer, and whose windstorm insurance may be more affordable. Other potential more immediate and instrumental users of the research data itself are builders and inspectors who will have a more accurate building code with which to work. At this time, since FCMP research is ongoing and data are still being collected, benefits for ultimate potential 'users' are still "in the pipeline". However, other research groups are currently using or planning to use the FCMP research products in their research in ways that should benefit the potential ultimate 'consumers'. These projects include work to facilitate the building or retrofit of safer structures, and provide better and more realistic insurance coverage.

Given this situation, the HLMP team decided it would be better to conceptualize these intermediate researchers as the current users, and have IPOR conduct qualitative interviews with several of them. Future HLMP focused evaluation studies should interview non-researcher "end users" (realizing that at that point the evaluation foci would include the other research groups as well as the HLMP itself as a program).

The team also feels that it is important to review the needs that became evident after Hurricane Andrew in many areas of hurricane vulnerability that led the state to fund the FCMP. Accordingly this report begins with that. Next is a brief summary of current FCMP work. Following that is a discussion of how its products are being used by the research groups mentioned above, and finally recommendations by the HLMP team.

SINCE HURRICANE ANDREW: THE NEED TO MEASURE HURRICANE WINDS ON THE SURFACE AND WIND LOADS ON STRUCTURES

Hurricane Andrew demonstrated that Florida had much to learn about the effect of surface winds on homes and other structures. This compact but powerful storm caused immense wind damage. Many things became evident as the destruction was studied. The building code/inspection process was inadequate. Prior estimates of losses that insurance companies would have to cover were far too low. Most people did not have window protection and other structural mitigation measures in place. The low loss of life among people sheltering in homes that were destroyed indicated much needed to be learned about how houses disintegrate in hurricanes and how survivability can be enhanced. Mortality figures were also very low for mobile home park residents, but this probably was attributable to Andrew's remaining on a straight and easily predicted track for two days, providing time and motivation for a successful evacuation of the mobile home parks. The outcome could have been tragically different if, for example, Andrew had arrived on Monday morning after a sudden change of course and intensification and had caught most mobile home park residents in their vulnerable homes.

Hurricane researchers and structural engineers studied these effects of Andrew and the State of Florida and Miami-Dade County initiated changes in response to their work. The county developed a local mitigation strategy that became a model first for Florida and then for the nation. The county building code, inspection, and structural testing processes were all made much more rigorous and consistent. State agencies participated in the building code reform process, ultimately producing a new state building code. DCA initiated a statewide mitigation strategy and a number of successful programs to increase the hurricane protection of homes. It also began a research program focused on mobile home residents, the most vulnerable housing sector. The Hurricane Loss Reduction Program (HLMP) is an important ongoing framework for this work by DCA.

An unfortunate consequence was the withdrawal by the major insurance companies from providing homeowners insurance. An ad-hoc arrangement for windstorm coverage was accompanied by much higher rates, particularly for South Florida residents. It was clear that neither insurance companies nor State authorities knew what kind of rate and reinsurance structure would be sufficient and affordable for homeowners but not excessively risky or expensive for insurance companies for future strong hurricanes. A number of initiatives were begun to study what cost magnitudes could be expected in the future.

As these initiatives were starting in the mid-1990's a major shortcoming remained: inadequate precise knowledge about the variable magnitude of hurricane wind on the ground and how it affects structures. In Hurricane Andrew, as in most other strong hurricanes before and since, wind measuring devices on the ground did not survive the storm. Only higher-altitude aircraft measurements provided a basis for estimating winds at the surface. Studies of the patterns of damage in Hurricane Andrew led to better understanding of how hurricane winds worked at ground level and better methods for extrapolating from aircraft and airborne instrument measurements. This work still left considerable uncertainty about actual wind loads that could be expected on structures in a strong hurricane. For Andrew, extensive research over many years were required even to resolve whether it was a category 4 or 5 hurricane on the ground at landfall. With even this basic classification measure being uncertain, there was obviously even more uncertainty about what happened on the ground at specific locations. Extrapolating from wind measurement at higher elevations is imprecise because turbulence and other effects such as wind flow over the building itself exist at surface level. These factors made it important to find a way to measure the wind loads that could be expected to actually affect homes and other buildings during a hurricane.

For construction and building codes, engineers use wind tunnel testing and damage estimates to refine models calculating design wind loads for buildings leading to the ASCE 7-98 standard incorporated into the Florida building code. This prospectively made new buildings safer and provided reference goals for retrofit programs. It did not answer the question, however, of what actual wind loads could be expected to act on different parts of a house in an actual hurricane. Wind tunnel testing and models provide estimates but depend on an input of data on expected surface wind and wind loads. Results from structural testing of building materials, wind protection devices such shutters, etc. also needed estimates of wind effects for interpretation.

Lack of ways to measure surface hurricane wind was also a problem for the other hurricane damage and structural mitigation research areas. It was particularly problematic for those attempting to make good hurricane loss estimates for the insurance industry, government planners, and policy analysts. Generally the only way these estimates could be made was to determine a statistical relationship between hurricane magnitude and amount of damages that occurred in past hurricanes. Different statistical estimates were calculated for various types of construction: concrete block, wood frame, etc. Probabilistic models estimated the likelihood of different magnitude hurricanes affecting a given area, and damage functions derived from the statistical estimates were used to predict expected losses that would have to be covered by insurance. Work continued on the probabilistic models, but as with building codes, much depends on figuring out what kinds of wind on the ground could be expected from different magnitude hurricanes.

Even work on improving hurricane evacuation procedures is affected by lack of knowledge about surface winds. The principal incentive for evacuation is storm surge; evacuation is essential in areas near the coastline where lethal storm surges can be expected in a major hurricane. Slightly further inland, storm surge is usually not the prime risk, and evacuation decisions are more likely to be based on trade-offs (in terms of potential wind damage to the home, and wind/flooding risks to vehicles used in evacuation) between whether it is safer to stay at home or leave.

Clearly, methodological improvements were needed to measure hurricane wind on the ground and wind loads on built structures. As the DCA considered funding such research, it was forced to answer a difficult question. The DCA knew that a focused wind/structural engineering basic research effort was needed. Normally the state funds development of applied research and leaves direct funding for basic research to federal agencies like the National Science Foundation (NSF). But NSF and similar agency funding entails an extended series of processes (requests for applications, proposal reviews, project awards and completion, report and article writing and publication, and evaluation of the results). If this route was taken, waiting for its completion even to begin funding applications for construction, insurance, and mitigation, Florida residents would remain with inadequate protection and high costs to cover the uncertainty for many years. Thus, the DCA decided to move ahead and fund the Florida Coastal Monitoring Program (FCMP) in 1998. By funding this project, DCA felt it could accelerate the process of getting usable hurricane mitigation applications from research efforts. This prospect was further enhanced because DCA was in the position to directly coordinate the FCMP work with other mitigation, insurance cost modeling, and related projects it funds.

OBJECTIVES OF THIS REPORT

As noted above, the purpose of this report is to evaluate the work of the FCMP program. The science and structural engineering work will not be directly evaluated in this report -- that is not the expertise of the IPOR team. For such an evaluation, experts would have to refer to the presentations and publications of FCMP engineers and scientists. In this light it is particularly useful to DCA that FCMP personnel have pursued an active publication and presentation program. The high esteem of FCMP work, expressed by researchers interviewed, is also evidence of the validity of FCMP research.

OVERVIEW OF THE CURRENT WORK OF THE FCMP

FCMP is currently deploying two types of instrument ensembles to measure hurricane wind fields near the surface. One consists of portable towers that collect data on wind at two different elevations. These towers can be rapidly moved to locations where hurricanes are approaching. The second type of instrumentation is on 32 individual homes along the Florida coastline (figure 1). These homes are wired and connected to instrumentation so that, if a hurricane is approaching, sensors can be quickly installed on different surfaces of the home. The project is also carrying out research to measure the strength of different components of buildings as they resist wind loadings expected in hurricane.

Since the towers are mobile, they can be towed anywhere along the Gulf or Atlantic coasts where hurricane wind data can be collected. This was done successfully in 2003 during Hurricane Isabel (figure 2), when the instrumented towers were able to collect data after other measuring devices had failed. The instrumented houses, being immobile, are able to collect significant amounts of data only when a major hurricane makes landfall at one or more of their locations on the Florida coast. The sensors were deployed to instrumented houses for hurricanes Floyd, Michelle and Isidore, but none of these made landfall in Florida. The FCMP researchers were able to secure additional funds from Sea Grant to instrument five additional houses along the Carolina coast by leveraging the existing FCMP infrastructure. The FCMP researchers are working to utilize the DCA investment in a cost-effective manner by generating outside support.

Hurricane Isidor did pass close enough to the Florida Panhandle (figure 3) to enable collection of data from instrumented houses there in 2002. These data were compared with wind tunnel model studies of those houses at Clemson. The results indicate that the pressure coefficients used in the current building codes may in certain circumstances be highly inaccurate, and practical improvements can be made to the codes based on the study results. There is generally good agreement between model and full-scale measures on the instrumented houses with some underestimation of coefficients in the wind tunnel for a few locations. However, in a number of cases, both the full-scale and wind tunnel coefficients are significantly higher than the coefficients used in the building code (the code is underestimating loads in these cases). The instrumented houses were located in suburban exposures and these exposures were replicated in the wind tunnel studies. The coefficients used in the building code have generally been derived from tests on buildings in open exposures without surrounding buildings of similar size. The use of a single set of pressure coefficients in the building code regardless of exposure may lead to significant underestimation of design loads for buildings in suburban areas. More data is needed for a wider variety of full-scale buildings subjected to even more intense winds to corroborate and strengthen these significant conclusions. But the current indications are certainly troubling, showing a potential need for code revisions. This type of comparison of real full-scale Tropical Storm level winds vs. wind tunnel model and building codes is a good preliminary verification of the FCMP research approach. It is also good evidence for the importance of this research, because it is the first corroboration of recent studies in which wind tunnel testing and modeling shows potential wind loads on buildings exceeding those considered acceptable in the ASCE 7-98 standard.

Again, it is important to note that only very preliminary conclusions can be drawn, given the small amounts of data have been collected. The complex wind effects of hurricanes on structures will require extensive measurements for a full analysis. The FIU HLMP team believes it is essential that data collection in hurricanes from instrumented homes and towers be continued so that Florida will receive continuing, increased, and the maximum feasible return on its investment in the FCMP.

APPLICATION TO BUILDING CODES, STRUCTURAL MITIGATION, AND MATERIALS TESTING

To measure the effect of hurricane wind loads on structural components of buildings, a number of activities are necessary. Wind speed pressure turbulence etc. are measured as is being done by FCMP. Models of the relationship between resultant wind loadings and potential structural failure are developed and tested in wind tunnels and other instrumented wind generation devices. Materials and techniques used in construction and retrofit have to be tested against predicted wind loadings, and this testing also has to include wind-propelled materials such as flying debris. If standards have to be changed (and preliminary results from FCMP data and wind tunnel modeling suggest that may be the case), a process of further testing and negotiation has to be initiated so the major players in government, the construction and insurance industries, and homeowners are confident and accepting of the changes. (The recent adoption of the ring-shank nail is a specialized but significant example of the process.) The scope of changes that could result from FCMP research could be quite broad (perhaps more so than from the ring-shank nail research) and thus may require an even broader stakeholder group be involved in discussions. DCA, being the source of funding for much of this research, is well positioned to bring the major players to this discussion. An advantage in this regard is the extant advisory board for the CAT fund that represents major industry interests.

APPLICATION TO WINDSTORM INSURANCE

Modeling potential insurance loss due to hurricane winds requires two major activities: estimating both future hurricane winds and the damage they will produce. Various probability models have been developed by private companies to predict the likelihood of damaging hurricane force winds occurring at specific locations over specific time periods. Some of these have been developed for the insurance industry, and some for government. The Florida Department of Insurance is now funding research to develop a public domain model for this purpose. The second activity, which measures the amount of damage caused by hurricane force winds, requires the same steps discussed above to measure the effect of hurricane wind loads on structural components of buildings. The difference is that the work has to cover not only new construction and retrofitting, but also all types of existing structures. Interviews with researchers engaged in the Florida public domain model work indicate that findings resulting from FCMP research will be critical to determine how specific hurricane wind scenarios will translate into damage magnitudes.

OTHER APPLICATIONS (EVACUATION, FEDERAL PROGRAMS -- HAZUS, NOAA)

Deployment of FCMP instrumented towers in the path of Hurricane Isabel resulted in the only reliable coastline surface level wind measurements available to the National Oceanic and Atmospheric Administration (NOAA). The FCMP data was much more extensive and reliable than any the federal government previously had obtained under similar circumstances. It is already being incorporated to improve estimates of the federally funded HAZUS model system. As with the local mitigation strategy, work funded by Florida taxpayers benefits the nation.

No similar results pertaining to evacuation are yet available, but research conducted since hurricane Floyd shows that decisions to evacuate have to be determined on a localized basis. Risks from flooding on roads and wind damage to evacuating vehicles indicates that homes be considered the primary refuge in most cases. The key question, of course, is ‘How much risk?’. Here again, accurately predicting wind effects on structures will be very important in advancing evacuation advisory policies.

FINDINGS

1. In funding the FCMP, the DCA initiated research that will potentially have great benefit in mitigating the dangers of hurricanes and minimizing the costs of being prepared for them. A situation existed where it was not known how well preparation for actual hurricane wind damage on the ground is provided by building codes, insurance coverage, and other programs to make people safe from hurricanes. The research apparatus to answer these questions is now in place, and the first significant results have been obtained. Other research groups are already implementing procedures to use the data for better building codes and cost-effective windstorm insurance coverage.

2. No hurricane has made landfall in Florida since Irene in 1999, before FCMP data collection towers and instrumented houses were deployed. This was good for Florida residents but meant most necessary data collection could not be completed. As a result data collection needs to continue and the time frame for doing so is uncertain.

3. FCMP has worked to get additional funding to augment DCA's investment. Now that the FCMP research operation has proven by the Isabel tower deployment to be able to generate significant data for NOAA, more Federal funding should be available.

4. The research groups funded by the State that are starting to use FCMP data have the potential to get additional grants to augment DCA's funding of the data stream they need to have continued (or contribute to it directly). DCA and FCMP have not collaborated on a research development plan to direct and facilitate the overall State funded research effort, but they could do so.

FIGURES

Figure 1. FCMP deployment of instrumented houses. Picture credit: Forrest Masters, Kurt Gurley and Tim Reinhold: ppt ms: "Real-Time Observation and Modeling of Ground-Level Winds from Hurricane Isabel"

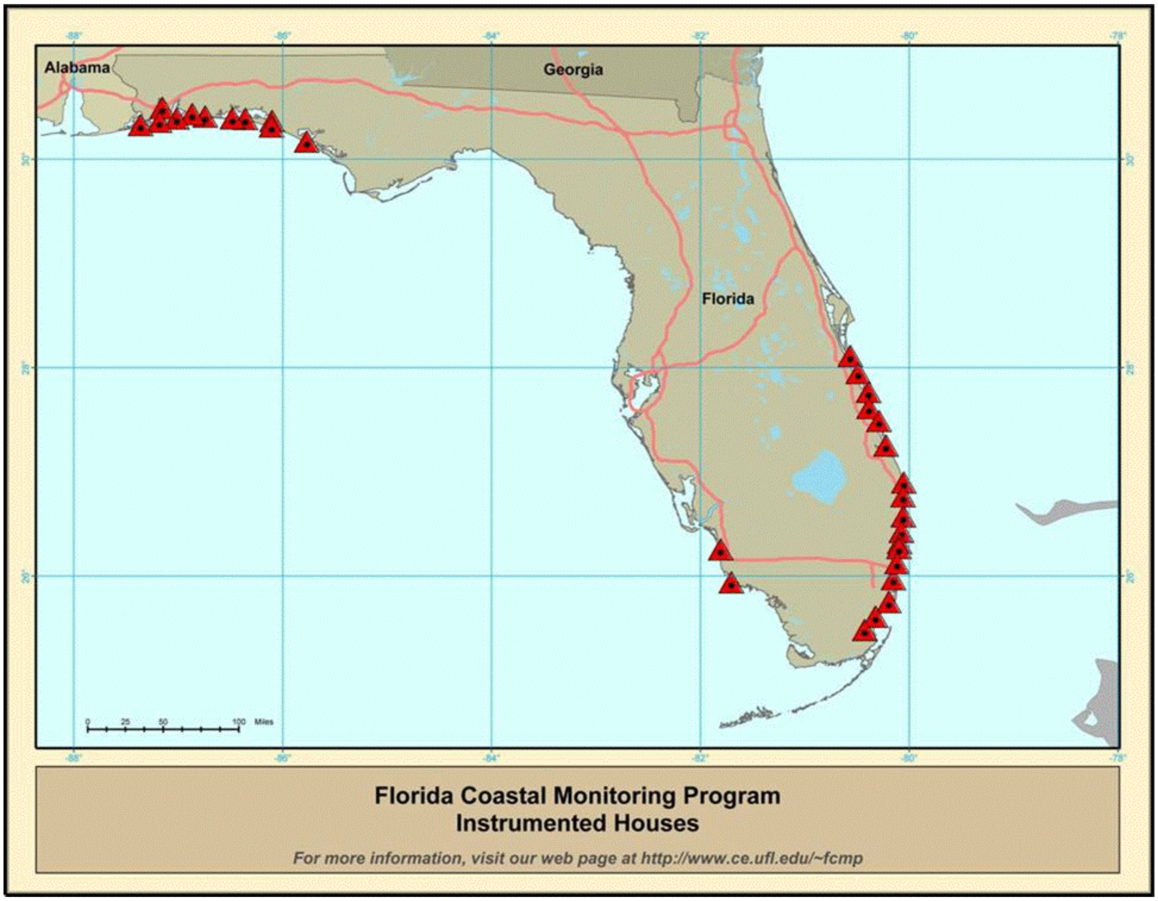


Figure 2. Hurricane Isidore track. Picture credit: National Hurricane Center Archive http://www.nhc.noaa.gov/prelims/2002isidore2.gif

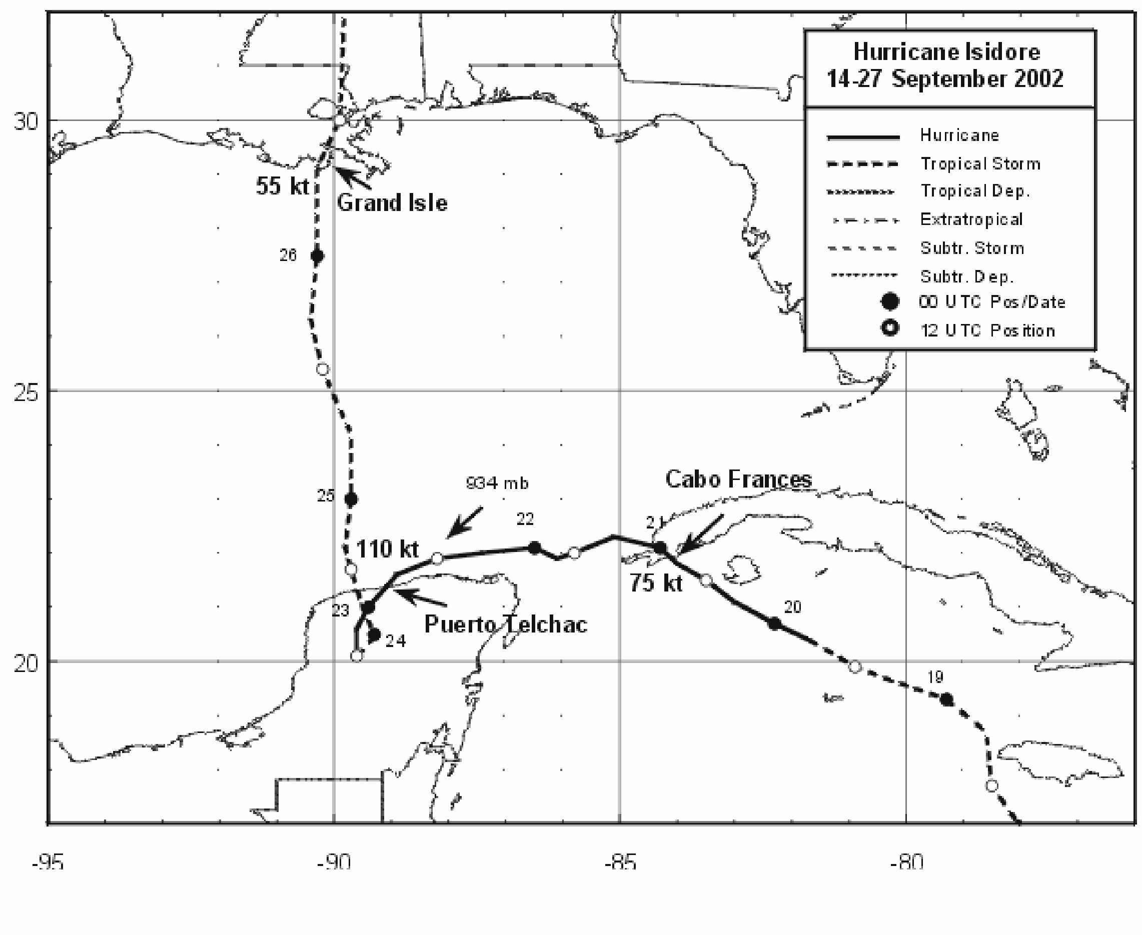
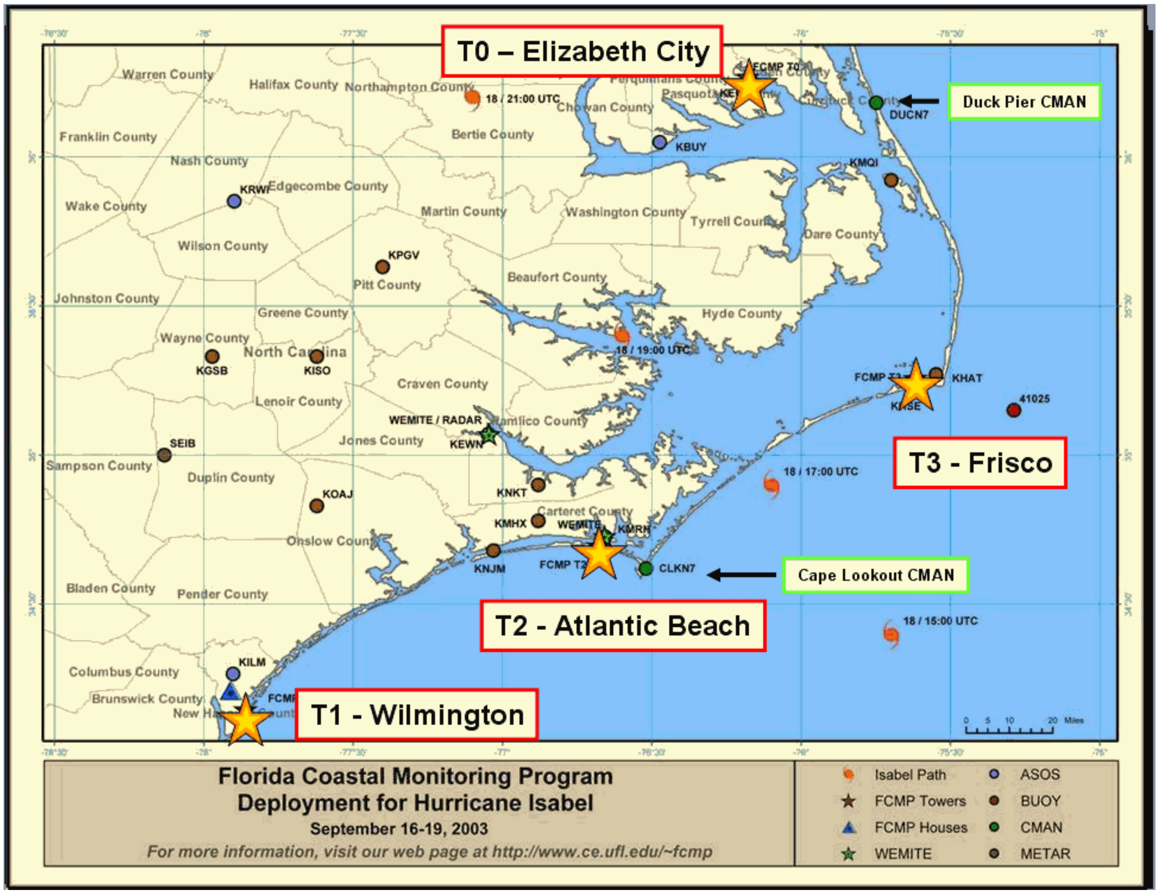


Figure 3. FCMP deployment of instrumented wind measurement towers for Hurricane Isabel. Picture credit: Forrest Masters, Kurt Gurley and Tim Reinhold: ppt ms: “Real-Time Observation and Modeling of Ground-Level Winds from Hurricane Isabel”



3.7 WORKSHOP TO REVIEW, UPDATE AND EXTEND PRIOR MITIGATION INCENTIVES RESEARCH AND PLANNING EFFORTS

This project is intended to investigate the 'Feasibility of Implementing Programs of Incentives to Include Hurricane Loss Mitigation Devices and Techniques in the Design/Construction of New Houses or in the Retrofit of Existing Houses.' It is within the 'Hurricane Loss Reduction Devices and Techniques' research track.

As originally proposed by the IHRC, the Laboratory for Social Science Research agreed to 'assess the feasibility of developing and implementing a program of incentives' for home-buyers who purchase new homes that include one or more hurricane loss mitigation devices or techniques.' In addition, a purpose of this research was to look at programs intended to provide incentives to existing homeowners to retrofit their houses with cost-effective hurricane loss mitigation devices or techniques. The study proposed to also look into potential sources and methods of funding such programs of incentives.

I. EXECUTIVE SUMMARY

The IHRC Team focused on completing the following key processes:

- Conducting electronic and library searches to determine which types of incentive programs are already in place or nearing implementation in Florida;
- Reviewing mitigation incentives work done earlier by and/or including IHRC;
- Organizing and conducting a workshop on prospective incentives for homebuyers and homeowners.

Key findings include:

- http://www.floridacommunitydevelopment.org/mitdb/, the Florida Department of Community Affairs website for mitigation information, continues to be the best and most authoritative source of mitigation incentive information for Florida homebuyers, homebuilders, homeowners and related organizations
- Four recommendations from the 1999 Homeowner Incentive Team report have been partially or completely implemented:
    - o discounted or waived building permits, plan check or inspection fees for retrofits in accordance with guidelines
    - o low interest loans for retrofitting
    - o 'recognition' for structures built in accordance with higher standards

    - insurance premium incentives
- HIT ‘progeny’ also include the:
    - Residential Construction Mitigation Program (RCMP), and
    - Federal Alliance for Safe Homes (FLASH)

Reanalysis of 1999 and 2003 statewide homeowner surveys revealed:

- Improvement statewide in 100% covered homes using code compliant materials
- Substantial improvement in this regard in wind-borne debris zone
- Significant reductions in homes with no protection in highest risk areas
- Yet, 48% have at best partial protection and 35% have no window protection
- Significant decrease in those that feel that they do not need window protection
- Significant increase in reporting of cost as main reason for not having them
- Additional frequent excuses: procrastination, appearance
- Minority households more likely to say cost main reason for not having shutters
- Lower income households were also more likely to report cost as a factor
- Households in higher wind risk (but not in 120 mph) zones also cited cost
- Low interest loans were not of interest to vast majority of surveyed homeowners
- Low interest loans significantly decreased in popularity as a mitigation incentive
- Forgivable loans were very interesting to 45% of those in each of the surveys
- Lower insurance premiums were very interesting to 38% and 41%
- However, only 22% reported getting insurance discounts for mitigation features
- Approximately 46% had no idea if their insurance company offered discounts
- Of those with complete coverage using code approved materials, 66% reported getting some form of discount
- Property tax reductions increased in popularity as incentive to mitigate (a modal response of ‘somewhat likely’ (37%) in 1999 but ‘very likely’ (44%) in 2003)
- Reductions of approximately 25% in both insurance premiums and property taxes were reported to be necessary for them to be mitigation incentives
- Overall, households appear to be increasingly responsive to all forms of incentives, with the exception of low interest loans

- Each type of incentive varies in attractiveness among different groups, but in general, incentives tend to be attractive to:
    - those with higher risk perception
    - households in higher risk areas
    - younger households (homes with children and no elder members)
    - households more recently occupying their homes
    - lower income households
    - minorities
- Hurricane risk perceptions of Florida's single family homeowners and Expert Risk Analysis (ASCE 7-98) show significant but far from perfect correspondence
- New home buyers responses indicate:
    - greater awareness and concern about hurricane safety
    - lack of knowledge, information about what is important
    - often don't have adequate resources to act on their awareness, concern, and knowledge
- A significant and increasing percentage of respondents indicated they were 'very interested' in a hurricane safety inspection program
- Single family owner-occupied home owners increasingly either:
    - can't easily undertake mitigation because of limited resources/ assets, or
    - still do not fully appreciate the nature of hurricane risk or what they need to do to properly undertake effective wind hazard mitigation

Analysis from a 1998 survey conducted in South Florida revealed that:

- Homeowners in multi-family units were much more likely (48% in 6+ units and 44% in 2-5 unit buildings) than single family homes (26%) to have 'nothing' as shuttering or opening coverage
- A majority of residents of rental housing (51% in single family, 69% for families in 2-5 unit buildings, and 75% for families in 6+ unit buildings) reported having 'nothing' as shuttering or opening coverage

Key recommendations include:

- The Florida Department of Community Affairs website for mitigation information http://www.floridacommunitydevelopment.org/mitdb/ can be much more cogent for all consumers by:
    - facilitating mitigation incentive comparisons among insurance carriers
    - including specific insurance premium mitigation incentive information for condominium owners/associations, landlords and renters

    - providing links to websites of other organizations that provide goods and services that facilitate and/or provide incentives for mitigation
- Develop mitigation incentive programs that feature forgivable loans, because property taxes, and insurance premium discounts as incentives, while favored by homeowners, are probably unacceptably expensive
- Improve the availability and accessibility of information, both on existing insurance mitigation incentives and any new incentives, because no single incentive or combination will be effective if unknown to consumers
- A hurricane safety inspection program should be cautiously explored
- Mitigation incentive education programs should target potential home buyers and realtors, perhaps as an extension of general population programs
- Mortgage programs that allow buyers to finance wind hazard mitigation improvements as part of the original purchase should be considered
- Reduced fees and similar incentives for purchasing a home with wind hazard protection features should be considered
- Research should be conducted to identify issues of knowledge, attitude, willingness and ability to respond to hurricane mitigation incentive programs and the nature of incentive programs most likely to be effective for:
    - home owners in multi-family buildings
    - owners of commercial residential (rental) property, and
    - renters in both single and multi-family buildings

II. INTRODUCTION AND OBJECTIVES

Scope of Work:

Through discussion with the IHRC Project Directors Mr. Ricardo Alvarez and Ms. Carolyn Robertson, the investigators developed a research plan to conduct a **Workshop to Review, Update and Extend Prior Mitigation Incentives Research and Planning Efforts**. Specifically the project was designed to be conducted as three interrelated components, as follows:

1. Conduct web/internet searches and library research to determine which types of incentive programs are already in place or nearing implementation in Florida. The results of these analyses were to be made available to DCA for its discretionary inclusion in printed and electronic/website materials that it would disseminate.

2. Review mitigation incentives work done earlier by and/or including IHRC. This was decided to include:
    a. the Homeowner Incentive Team (HIT) process and report (1999)
    b. statewide and regional surveys of homeowners that included mitigation attitude, action, and preference questions

3. Organize and conduct a one-day workshop to discuss the merits and drawbacks to prospective incentives and which might be good candidates for offering to homebuyers and homeowners. The approach to this workshop was to identify and assemble key stakeholder representatives, i.e., representatives from corporations, agencies, and sectors of the housing construction, retrofitting, insurance, financing, etc. markets. Workshop participants were to be presented with analysis from the surveys and a DCA-provided update on recommendations from the HIT report. They were then to be asked to discuss what they had seen and heard and to respond with recommendations for continuing and future mitigation incentives initiatives. The investigators and FIU faculty experts were proposed to facilitate the workshop, record the discussion, and summarize the conclusions agreed upon.

The following report summarizes the results of the efforts outlined above.

III. METHODS

Literature Search/Review

Project staff used a variety of search engines and search phrases to identify websites and electronically accessible sources. An initial master listing of URL's was compiled from searches conducted by individual research assistants and associates and a second round of visits and annotations was conducted to narrow the listing to those which contained specific and 'actionable' information. The results of this search process are summarized in the findings section below.

Homeowner Incentive Team Report (1999)

An earlier project under this continuing series of applied research investigations involved the creation of a Homeowner's Incentive Team (HIT) to identify and develop a comprehensive set of financial and administrative benefits to homeowners that would inspire them to take steps to strengthen their homes before a natural disaster. In 1999, the HIT produced a report which proposed a set of recommendations of incentives to induce homeowners to mitigate their homes. These recommendations are included verbatim in Appendix A.

Given that several of the HIT Report recommendations were appropriate and intended as first steps in the creation of legislative language and presentation for consideration by both local governments and the State legislature, and given that these recommendations were now almost five years old, the investigators on the current project concluded that it would be useful to see which, if any, of the recommendations had resulted in legislative action. Further, it was thought to be potentially useful to revisit those recommendations to see if the passage of time might have changed the attractiveness of any of the recommendations that had not been implemented to date.

The means chosen for this update and review was a Workshop in which a Department of Community Affairs representative would provide the most current and authoritative information on legislation that may have resulted from the earlier recommendations. Mr. Charles McCool, Administrator of the Residential Construction Mitigation Program for the Department of Community Affairs accepted the research team's invitation to research the topic and make a presentation at the planned Workshop. The participants would be representatives invited to attend from the same organizations that had provided representative for the original HIT process plus a few additional ones (see Workshop description below).

Mitigation Survey Research Analysis

Dr. Walter Gillis Peacock, Texas A&M University, was contracted by the IHRC LSSR to re-analyze and summarize the findings on mitigation preferences, actions, and attitudes from three surveys done in 1998 (Southeast Florida), 1999 and 2003 (Statewide). These surveys included questions about incentives for home-buyers and the analysis proposed for this project was to determine which might be more effective in persuading them to include or retrofit their homes with hurricane loss mitigation devices or techniques. The surveys were conducted as joint projects of the IHRC Laboratory for Social Science Research and the FIU Institute for Public Opinion Research (IPOR). The means chosen to present these summarized analysis was to include Dr. Peacock as a presenter and discussant at the planned April 1, 2004 workshop that would be attended by one or more DCA representatives. This approach had the additional advantage of making the survey research findings available to the other workshop participants for them to consider in their discussions and recommendations.

Workshop

Florida International University's Mitigation Incentives Workshop was held on April 1, 2004. Its purpose was to use statewide homeowner survey research findings and an update on results from the 1999 recommendations made by the Homeowner's Incentive Team (see Appendix A) as input for a group of informed and invested stakeholders in various aspects of the home buying/selling/financing/insuring and construction/retrofitting industries. The summarized information and the combined and varied experience and expertise of the invited participants were intended to stimulate discussion and produce further recommendations for mitigation incentives for the benefit of both DCA and the the participants own organizations. Dr. James Rivers, Director of the Laboratory for Social Science Research and a workshop steering committee (See Appendix H) compiled an invitation list that began with organizations and participants involved in the earlier HIT meetings. This listing was supplemented with additions from appropriate other organizations. Those invited to the workshop included representatives from banking, the building industry, utilities, government, insurance and real estate as well as other organizations that manage commercial residential properties. (See Appendices D, E, F, and G for sample invitation, agenda, invitees and list of participants). A summary of the participants' discussion during the workshop is a later section.

IV. FINDINGS AND RECOMMENDATIONS

Literature Search/Review

The most authoritative source of information regarding mitigation incentives available to Florida homebuyers and homeowners is the website maintained by the Florida Department of Community Affairs at the following URL: http://www.floridacommunitydevelopment.org/mitdb/.

This website informs Florida homeowners and builders about the incentives that are available for making homes better protected against wind damage. For example,

- Florida Statute 627.0629 mandates that all insurance companies offer Florida homeowners "discounts, credits, or other rate differentials…"for construction features that protect homes during windstorms.

- By March 2003, Florida insurance companies had to submit filings for wind mitigation discounts that would begin to take effect that year. The website has links to an incomplete list of insurance companies doing business in Florida that is intended to allow consumers to 'shop' among these companies for wind insurance coverages and discount plans/features that are discretionary for each company.

- This website notes that Insurance discounts are available for single family and duplex houses, condominiums and tenant occupancies from various carriers, but that specific information on these discounts are not available via the DCA website.

- The website notifies residents of Miami-Dade and Broward Counties whose homes were built after 1994 and residents of the rest of Florida whose houses were built after 2002 that their residences may already have wind protection features that qualify for insurance discounts.

Another source of mitigation incentive information is the website maintained by the Citizens Property Insurance Corporation Wind Classification Plan at http://www.citizensfla.com . This plan offers up to fifty percent savings on insurance for mitigated homes.

Various websites for specific insurance companies have information on their companies' mitigation incentives and discounts. In addition, some websites for disaster and emergency services organizations, e.g. American Red Cross, various county offices of emergency management, local mitigation strategy groups, have links or suggestions to consumers re: where to find products or services that include mitigation incentives.

In summary, http://www.floridacommunitydevelopment.org/mitdb/, the Florida Department of Community Affairs website for mitigation information, continues to be the best and most authoritative source of mitigation incentive information for Florida homebuyers, homebuilders, homeowners and related organizations. However, this website can be much more cogent for all consumers by:

- facilitating mitigation incentive comparisons among insurance carriers
- including specific insurance premium mitigation incentive information for condominium owners and associations and owners and residents of commercial residential properties, and
- providing links to websites of private and public sector organizations that provide goods and services that facilitate and/or provide incentives for mitigation

Homeowner Incentive Team Report (1999)

Mr. Charles McCool, Administrator of the Residential Construction Mitigation Program for the Department of Community Affairs reviewed the recommendations from the 1999 Homeowner Incentive Team report on April 1, 2004 at the Incentives Workshop held at Florida International University. His entire graphics and textual workshop presentation and report are included as Appendix B to the current report.

Mr. McCool explained the DCA context for the Homeowner Incentive Team initiative (part of a larger Long Term Redevelopment effort), the composition of its advisory steering committee, and identified FIU IHRC as the contracted agent to organize and support the effort.

His report noted 17 incentives of different types and sectors (public and private) that were proposed at various points in the 1998-1999 life of the HIT and the LTR Unit. He identified four (4) incentives that have been or were implemented in whole or in part:

1) discounted or waived building permits, plan check or inspection fees for retrofits in accordance with guidelines

2) low interest loans for retrofitting

3) 'recognition' for structures built in accordance with higher standards

4) insurance premium incentives

Mr. McCool's presentation noted that, in addition to the legislatively mandated insurance discounts for mitigation construction or retrofitting by homeowners, the HIT 'progeny' also included the

- **Residential Construction Mitigation Program (RCMP), and**
- **Federal Alliance for Safe Homes (FLASH)**

His presentation concluded by saying:

> "At the end of the day… HIT was an ambitious program which resulted in (organic) programs and incentives that encourage homeowners to incorporate mitigation into their home building and retrofitting plans, thereby protecting life

and property in the State of Florida…therefore indeed helping Floridians and their businesses and governments to ‘Break the Cycle’ “

Mitigation Survey Research Analysis

Mitigation survey research that had been conducted in recent years in Florida by Dr. Peacock, researchers from the FIU IHRC Laboratory for Social Science Research (LSSR), and by Dr. Hugh Gladwin, Director of the FIU Institute for Public Opinion Research (IPOR) was re-analyzed and summarized by Dr. Peacock to examine the degree to which Florida’s single family homeowners are prepared for hurricanes. This survey research focused on how well protected owner-occupied single family homeowners are throughout the state of Florida and if they are not protected, whether they were considering getting protection for their homes. Dr. Peacock’s entire report for this workshop is included as Appendix C in the current report.

The presentation addressed four topics:

1) Mitigation status of Florida’s single family owner occupied homes

2) Responsiveness of those without adequate wind protection to various incentive programs that may or may not be offered by governmental or non-governmental agencies

3) Characteristics of those households that might be responsive to different types of incentive programs

4) Mitigation status of all Floridian’s homes

The following is an outline of his key findings.

Findings

1) Substantial improvement in the percentages of homes with 100% coverage using code compliant materials (slide 4)

2) Significant reductions in homes with no protection in highest risk areas (slide 4)

3) Substantial improvement in the percentages of homes with 100% coverage using code compliant materials in wind-borne debris zone (slide 5)

4) Significant reductions in homes with no protection in highest risk areas (slide 5)

5) And yet, 48% have at best partial protection and 35% have no window protection (slide 5)

6) Significant decrease in those that feel that they do not need window protection (slide 6)

7) Significant increase in households reporting that cost was the biggest reason for not having them (slide 6)

8) Other reasons: procrastination, would look bad, not sure… (slide 6)

9) Minority households were more likely to report that they cost was a main reason for not having shutters (slide 7)

10) Not surprisingly lower income households were also more likely to report cost as a factor (slide 7)

11) Households in higher wind risk zones also reported cost (but not those in 120 mph) (slide 7)

Low Interest Loans: similar response pattern when comparing 1999 with 2003:

12) However much lower percentages indicate they are either very or somewhat likely to be motivated by a low interest loan (slide 9)
13) The vast majority are not interested at all in low interest loans (slide 9)

Forgivable Loans (similar to early RCMP): Somewhat different response pattern when comparing 1999 with 2003:

14) Similar percentages indicating they are very likely to be motivated by forgivable loans (slide 10)
15) But, the percentages for the other two groupings have reversed (slide 10)

Lower Insurance Premiums: Very similar response patterns when comparing 1999 with 2003:

16) Slightly more pronounced difference between very and somewhat likely in 2003 (slide 11)
17) However, the same pattern is evident, the highest percentage are report that they are very likely to respond to lower insurance premiums (slide 11)

Note:

a. Statewide, only 22% reported getting insurance discounts due to hurricane safety features (slide 12)
b. Nearly 46% had absolutely no idea if their insurance company offered discounts (slide 12)
c. Approximately 66% of households with complete coverage using code approved materials reported getting some form of discount (slide 12)

Property Tax Reductions: Different response patterns emerge when comparing 1999 with 2003:

18) The 'somewhat likely' response is dominant in 1999 at 37%, with the other responses hovering between 31 and 32% (slide 13)
19) In 2003 however, the 'very likely' response is pronouncedly dominate at 44%, with 30% responding "somewhat likely" and 26% responding "not likely." (slide 13)

Magnitude of property tax and insurance premium reductions from mitigating: Findings are remarkably similar when comparing both 1999 and 2003 results and when comparing tax and premium reductions.

20) The median tax and premium reductions are 25% with mean values hovering between 27 and 28% (slide 14)
21) On the whole the values are highly positively skewed (not reflected in the plots), hence the median values might be most appropriate (slide 14)

In summary, on the whole, there are considerable differences in the response patterns between 1999 and 2003:

22) Households report being much more responsive to reductions in property taxes and insurance premiums (slide 15)
23) Households appear to be much more responsive to all forms of incentives, with the exception of low interest loans (slide 15)

Positive response to incentives by household types:

- **Low-Interest Loans:**

24) Those with higher hurricane risk perception (slide 18)
25) Lower income households (slide 18)
26) Younger households (with children and without elders) (slide 18)
27) Those with hurricane experience (slide 18)
28) Those in higher risk wind zones (slide 18)

- **Forgivable Loans:**

29) Younger households (non-elder households and those without elder members) (slide 18)
30) Households that have been in resident shorter periods of time (slide 18)
31) Slight tendency for minority households (slide 18)
32) Those with higher hurricane risk perception (slide 18)

- **Lower Insurance Premiums:**

33) Younger households (non-elder households and households with children) (slide 19)
34) Households that have been in resident shorter periods of time (slide 19)
35) Those in higher risk wind zones (slide 19)

- **Lower Property Taxes:**

36) Younger households (non-elder households and those without elder members) (slide 19)
37) Households that have been in resident shorter periods of time (slide 19)
38) Those with higher hurricane risk perception (slide 19)
39) Households in higher risk areas (slide 19)

- **In general:**

40) Those with higher risk perception (slide 20)
41) Households in higher risk areas (slide 20)
42) Younger households (homes with children and no elder members) (slide 20)
43) Households more recently occupying their homes (slide 20)
44) Lower income households (slide 20)
45) Slight tendency toward minorities (slide 20)

The importance of risk perception:

46) There is a good degree of consistency between Hurricane Risk Perceptions of Florida's Single Family Homeowners and Expert Risk Analysis (ASCE 7-98), but the correlation is far from perfect. More needs to be done to address discordance (slide 21)

The importance of hurricane safety among newer home buyers:

47) Among more recent home buyers there is greater awareness and concern about hurricane safety (slide 22)
48) But new home buyers often don't receive or find the type of information about what to look for and what is important, (slide 22), and

49) New home buyers often don't have adequate resources to act on their awareness, concern, and knowledge (slide 22)

Interest in hurricane safety inspection program:

50) Similar patterns in 1999 and 2003, but slightly and significantly more households in 2003 suggest they are 'very interested' in an inspection program. The nature of the program will be important (slide 23)

Two general themes from survey results of single family owner-occupied housing:

51) Much has been accomplished, but single family owner-occupied home owners increasingly either:
    a) can't easily undertake mitigation because of limited resources/ assets, or
    b) still do not fully appreciate the nature of hurricane risk or what they need to do to properly undertake effective wind hazard mitigation (slide 24)

Shutter Usage: Owners of single family and other forms of housing

52) Homeowners in multi-family units were much more likely to have 'nothing' (48% in 6+ units and 44% in 2-5 unit buildings) than single family homes (26%) and correspondingly much less likely to be '100%' code compliant' (slide 27)

Shutter Usage: Rental housing

53) Residents of rental housing are at much higher risk-level re: shuttering in that a majority reporting having 'nothing' as shuttering or opening coverage (51% in single family, 69% for families in 2-5 unit buildings, and 75% for families in 6+ unit buildings)

Recommendations:

Incentive programs:

1) Low interest loans are not likely to be well received (slide 25)
2) Forgivable loans, lower property tax, and insurance discounts seem to be the preferred incentive programs (slide 25)
3) More generous tax and insurance discounts as incentives are probably untenable, given amounts desired by home owners (slide 25)
4) A combination of incentives is probably preferable, but no combination will do much if there is very limited information about what is available (as is the case with insurance discounts). (slide 25)

Inspection programs:

5) Perhaps something to be explored, but with caution (slide 26)

Education programs:

6) Especially for potential home buyers and realtors (perhaps extended general education programs) (slide 26)

Mortgage programs:

7) Programs that will allow buyers to finance wind hazard mitigation improvements as part of the original purchase are needed (slide 26)

Reduced fees, etc.:

8) For purchasing a home with wind hazard protection features (slide 26)

Housing other than owner-occupied single family dwellings:

9) Conduct research to identify issues of knowledge, attitude, willingness and ability to respond to hurricane mitigation incentive programs by home owners in multi-family buildings and the nature of incentive programs most likely to be effective for these consumers (slide 27)
10) Conduct research to identify issues of knowledge, attitude, willingness and ability to respond to hurricane mitigation incentive programs by owners of commercial residential (rental) property, by renters in both single and multi-family buildings and the nature of incentive programs most likely to be effective for these consumers (slide 28)

<u>Workshop</u>

Discussion Summary – *Note that comments made during the workshop were transcribed as closely as possible and every effort was made to retain their meaning in the context in which they were presented. Figures and facts are presented as stated. The following summary may therefore contain imprecise or factually incorrect information, but is representative of the lively discussion.*

In Miami-Dade County 30% of housing consists of single-family owner occupied homes. The 1999 HIT recommendations focused on these homeowners and were developed to encourage homeowners to mitigate their structures. Though efforts are still being made to provide incentives to this group, other vulnerable communities remain. Condominiums and apartment buildings provide housing for a group of residents who are alarmingly vulnerable to damage from hurricanes. These groups present complex issues because their ability to modify their housing is restricted or prohibited. In order for these types of housing to be mitigated, incentives that target the owners of the complexes must be developed.

Workshop participants were asked for their general comments following presentation of the 1999 HIT recommendations. One participant suggested that the word mitigation should not be used with the public for educational purposes, since it sounds like litigation and thus may have negative connotations. Instead, words like “fortified” and “protection” and “safety” may be more effective (according to State Farm public awareness and educating campaign findings). The group agreed that there is a need for finding innovative ways of reaching people, since even if the public is aware of the risks posed by hurricanes, they are not inclined to take action to mitigate their homes against damage without incentives.

Working primarily with Associations to address mitigation incentives has not been successful, one participant claimed, because they don’t have the power to make individual banks (or insurance companies, or whomever they represent) take action. Instead, they must be approached individually.

Multiple incentives from a variety of sources were seen as likely to be more effective in encouraging mitigation actions; that is, insurance incentives are necessary, but not sufficient. It was suggested that every company that gives a product or service to homeowners should also provide an incentive for hurricane mitigation.

With regard to insurance, one proposal was that there should be different insurance premiums for compliant and non-compliant homes, a type of “forced compliance.” For example, Architect/Engineering firms, Contractors, Financial Institutions, Permit Agencies, Universities and Property/Bank Appraisers should give higher appraisals to homes that are up to code, have shutters, etc. In that way, new home buyers would appreciate the reduced insurance rates of compliant homes, while realtors’ fees would increase.

Demonstration projects conducted by the Wharton School of Business were briefly mentioned; they consisted of roundtable discussions on disaster-resistant structures and incentives. The result was two pilot programs: one studying earthquakes (Berkeley), another, hurricanes (NC/Wilmington). In the hurricane pilot program, the mayor and city officials collaborated to offer some incentive as a test case. The question was: If there are incentives available, will homeowners comply? This was discussed because of its similarities to the situation in Florida.

Following this period of general comments, participants were asked to discuss incentive strategies specifically in terms of: Insurance; Financing for construction and retrofitting; Tax Rebates; Condominium Associations; Commercial Residential Property Owners. Dr. Rivers moderated the discussion, with attention to the following questions (as brought up by the participants):

How do you keep a scorecard of what is working?
Who's keeping track?
How are we doing? (surveys)

Insurance

Rates and premiums were the initial focus of the discussion among participants, namely allowing companies to charge more for those homes that are non-compliant. Applying differential rates was suggested, such as credit for compliance or raising rates for non-compliance. A trained third party independent inspector with a license would have to be appointed to examine mitigation actions, and issue some type of a "licensed contractor" report. If the building permit was issued after a certain date (when codes changed), the changes would be automatically approved since the assumption would be that the work done was up to code. Participants emphasized that a standard has to be set for retrofitting in the same way that there is a new code for new building.

A contradiction in rates was mentioned, namely that those homes that sustained damage during Hurricane Andrew are in high risk areas and consequently don't have good insurance coverage now, and the cost is high, since many companies are no longer writing policies in these areas. However, in Miami one company, the Citizens' Group, does offer a discount on houses East of US1 (high risk coastline area). Since other insurance companies won't write policies in Miami-Dade County, Citizens' is the only option.

Insurance companies don't actually know effects of mitigation when disaster occurs (in terms of their cost of repair afterwards). It was suggested that they would be interested in knowing: are the efforts worth it? Are they cost effective? A model comparing costs (of insurance policies) does exist. Rate loss relativity studies will provide uniform formulation for insurance companies – put more things into mitigating the home, get more money off the premium – but still the same discretion exists in terms of each insurance company setting their own premiums. So, the question arose: What would make insurance companies adopt recommendations? State law could be created to impose discounts. Houses should be certified so that it would be clear (in the cases of older homes) what benefits the owners receive. Mortgage lenders need adequate insurance (which is affected by the home's value) to replace homes. Anti-trust laws that save insurance companies money also save policyholder's money.

Condominiums and multi-unit housing were also discussed, since their situation can be quite different from single-family homes. For instance, condominiums need to be well protected because people do not want to leave when a hurricane is approaching. In terms of the mitigation efforts, there was the question of why would any condo owner shutter their unit if the rest don't, since the integrity of the building is compromised if everyone doesn't shutter. Since shutters are to protect the structure, not the contents of dwelling, there is even less incentive for individual owners to shutter if it is not required. Some condominium associations do not have insurance, though it is mandated by law. Furthermore, some condo associations don't have adequate insurance (e.g., 80 unit building might be under-insured). In other words, unless there is a loan on the property, there is no guarantee on mitigation factors.

However, if a multi-unit building has no loan, they may have no insurance, and then there is no control over their actions by law. There must be a very large economic incentive for multi-unit building owners because mitigation is so much more expensive for buildings. However, there should be a check on the price (of mitigation procedures) so the responsibility does not fall entirely on the renters.

In terms of condo associations and landlords – legislative actions (current) regarding insurance are lacking. For single family homes, the government is requiring incentives for insurance, while for rentals and condos, the same situation doesn't exist. In a condominium, there must be consensus voting – thus, 75% would have to vote to require shutters.

The Building code should be changed to encourage retrofit up to mitigation standards (would have to be based on an agreed upon mitigation standard). New owners have to make buildings satisfy the Building Code. This is also true when owners refinance their homes. If one must upgrade fire and sprinkler systems when purchasing a property, why not require upgraded windstorm protection measures? There is no recertification process when a property is resold. Banks do not require inspection. If the building code is not up to mitigation standard, then the sale of the building or home is not possible. Further, when a claim is presented to an insurance company for damage to a roof or window they could require that all windows/roof be upgraded to mitigated or set standards.

Discussion turned to government assistance, in that there is a misconception that FEMA will help and will rebuild homes after a hurricane. In fact, the average reimbursement check for a home is only $3,000. FEMA offers limited assistance to renters – they may get a few months rent as compensation for loss. FEMA does offer an “Individual Assistance Program” however many people do not know how to get funds or the assistance to mitigate. Also, a standard policy may not cover water damage. There needs to be education about policy coverage. For example, many residents in the Sweetwater section of Miami (which is not in a flood zone but actually floods often) do not have adequate flood insurance, in spite of the fact that flood insurance is very inexpensive. FEMA will look at what insurance homeowners could have had, and deduct that from any reimbursement. When tornadoes damaged homes in Homestead, the county condemned the homes, resulting in lack of availability of loans to rebuild. Homes with damage can be helped; those that are destroyed cannot.

Other suggestions included property-tax reductions, caps on insurance premiums or setting a base for a 5-10 year period.

Loans and Financing

As with all incentives, participants felt that a combination of different types of incentives would be most effective – loans alone won’t work. Loans would also have to be available from all levels of government (local, state, federal & private). The types of loans that could be offered were discussed, including low interest or forgivable loans, tax abatement during the life of the loan, or capping property value so taxes don’t go up even if there are improvements made to the home. Forgivable loans could be useful because the government only loses money for a few years.

At this time, Department of Environmental Resource Management (DERM) enforces banks to offer CRA (Community Redevelopment Act) loans, however this is not profitable. A conundrum exists: if the terms are market-regulated, it will not work unless everyone does it. Volunteer programs do not work because there is not much altruism between groups. It is a question of the carrot (reward) or the stick (punishment) method, which seems to always revert back to the stick, or exacting legislation requiring private insurance companies to provide policies in Florida. Florida is a “managing state,” which means other states use Florida as a model for how to mitigate effectively. This results in certain advantages from the federal government.

On the other hand, incentives to take action could be in the form of a carrot. For example, a standard could be set for hurricane safety in the same way it was for automobiles (e.g., air bag, anti-lock brake discounts). An appraiser could quantify the value of the house; the rule/standard would have to come from the Institute of Appraisal. There is difficulty in evaluating value/worth because of the wide diversity of houses. Also, appraisal is not an exact science. Appraisers should be trained in how to assess the value of mitigation. This would require cooperation of both the insurance industry and the financing industry. Some type of pilot project was suggested to investigate these issues. For example, a home improvement loan could be based on planned improvements. The changes would be made during the off [non-hurricane] season [November – May]. A group of banks or private lenders would voluntarily agree to get together to offer such a loan. This would require some type of recognition that mitigation has financial value (e.g. granite counters or a new kitchen add value to homes, the seller could make more money with these types of upgrades). Or, there could be a special program to get private lenders and government lenders (Fannie Mae, Freddie Mac, FHA) together to come up with a program.

Other suggestions included not adding the retrofit to the deed, such that the improvements would not be taxed. Thus, a house originally valued at 150K before the retrofit would actually increase to 170K in value, but for purposes of taxes the price would remain at 150K (not a selling price, just for the tax assessment). Banks/finance industry could offer a reduction in loan costs, no closing costs, or no points on loans used for mitigation. The bank could say it is “donating those funds to the mitigation effort.” Recognition should be given to corporations and companies who participate in the efforts to mitigate (LMS project.) Citibank does not charge closing costs for mitigated homes. For example, in the Citibank/LISC pilot program, shutter companies can partner with banks in a referral process.

Realtors could also be encouraged to market homes as “hurricane fortified” or “multi-hazard fortified” to add value to the home. With this type of plan using the FPL model of “Energy Efficient” terminology for homes they have declared as efficient, everyone could benefit (realtors, finance companies, the seller and the buyer) since the home has extra value. Realtors could charge lower percentages for disaster-resistant homes, if they are educated that their customers would be unhappy if their home doesn’t survive a hurricane, thus they would not get repeat referrals.

Regarding building materials and functionality, impact resistant windows are not only a permanent part of house, they also protect against gunshots, and breaking. Further, they require no action in preparation for a hurricane, unlike shutters. Thus, windows are in essence a passive system.

Shutters : Windows
Seatbelts : Airbags
(Active : Passive)

However, impact-resistant windows are extremely expensive to install and replace. Suggestions for enabling low-income/poor homeowners to take advantage of this type of mitigation included subsidized retrofitting; the state could get a number of people together and get discounted materials and installation. It was noted that just as airbags in automobiles were initially very expensive, the increased demand resulted in decreased price, thus the price of windows will likely also go down with increased demand.

Taxes and Other Incentives

- Cut impact fee (but depends on what impact fee is paid for, i.e. not roads)
- Dade County tax credit
- Studies that show benefits to utilities ($ figures)
- Federal tax reduction – mitigation should be tax deductible

Recommendations and Conclusions

1. Paradigm Shift
   The focus of who makes the decision to mitigate should shift from individual homeowners to policy/decision makers.
2. Education – Disseminating facts, and getting the right message out
   - While universal education is required, socioeconomic status determines primary focus of effort required
     - o Low income households – need help (financial)
     - o Middle income households– need convincing; education
     - o High income households – will do [without much effort]
   - It is important not to send the wrong message, such as conveying that one can protect their home so he or she does not have to leave when a hurricane approaches
   - Sell other benefits of mitigation (windows, etc.) – marketing & education
   - Impact resistant glass better than shutters, because shutters may not get put up

- Higher education is needed on what actual household risk is - not just their perception of risk

3. For Industry
   - Focus on what insurance companies gain by providing mitigation incentives
     - Incentives for single family homes, rental housing and condominiums should match
   - Make the value of mitigation clear to insurance companies
     - Phase-in getting them the information – later, all insurance companies will have to offer incentives
   - Market homes as “hurricane fortified” or “multi-hazard fortified”
   - Legislation is not the only answer to the problem – cooperation within industry to provide multiple forms of incentives is encouraged
4. Next Steps
   - Get insurance companies writing policies in Miami-Dade County
   - Conduct surveys of landlords and/or condo associations to determine education needs based on existing attitudes, and actions intended and taken regarding mitigation
   - Focus mitigation efforts on windows, gables, roof tiles, garage doors
   - Train appraisers to assess the value of mitigation
   - Mitigation should be tax deductible
   - New owners have to bring buildings up to code (also for refinancing)

V. DISCUSSION

This project began with a narrow focus to examine structural hazard mitigation - commonly defined as measures that will reduce the potential for damage to a facility or structure from a disaster event – among owners of single family dwellings. This topic obviously has implications for hazard mitigation in a broader context, e.g. as sustained actions taken to reduce or eliminate long-term risk not only to property but to people and property from hazards and their effects. And since the research included ‘incentives’ that might be attractive to owners of single family dwellings to mitigate their houses, the research inevitably included some non-structural issues, e.g. education of home buyers, home owners, realtors, et al., knowledge, attitude, and social and economic factors. As emphasized in the Stafford Act definition of mitigation, it was important that the incentives be within the realm of potentially ‘cost-effective’, as well.

As can be seen in the analyses by Peacock, this project was also mindful of the fact that mitigation has different dimensions, e.g. (1) *exposure* – location relative to the potential hazard (in the case of hurricanes, proximity to the coasts where hurricane winds, storm surge, and fresh water flooding are most likely); (2) *probability* – likelihood, or even the perception of likelihood, that a hazardous event (hurricane) will affect a particular location; and (3) *vulnerability* - inability of (a) the earth and structures built upon it to withstand forces and (b) people to evacuate, protect themselves, and to cope with the event (physically and psychologically/emotionally).

Peacock's analyses of hurricane mitigation incentives survey research included consideration of exposure by examining some of the results by where the respondents lived, i.e. with reference to wind-borne debris zones identified by ASCE 7-98 and now incorporated into the Statewide Building Code. His analysis also provided data and discussion on perceptions of probability or risk and how this corresponded, albeit imperfectly, with geographic exposure. The survey analysis also provided some data and discussion relative to vulnerability, in that those homeowners with higher perceived risk and in higher risk areas, those who were younger and had more recently moved into their homes, who had lower household incomes and were minorities tended to be interested in mitigating but perhaps unaware of what is available and/or unable financially to benefit from it. Dr. Peacock's report also addressed vulnerability with the findings from a South Florida survey that many homeowners in multi-family units and that substantial majorities of residents of various types of rental housing reported having no shuttering or opening coverage at all.

These findings, and especially the latter information on renters, prompted an examination of 2000 census housing data for Florida to better understand the magnitude (occupied households and estimated population) and State geographic context of renters. The 2000 Census provides counts for **counties** of total occupied housing units (**TotOccHU**) and specifies whether they are owner-occupied (**OOccHU**) or renter-occupied (**ROccHU**). Simple arithmetic calculations yield the percentage of the total occupied housing units that are owner-occupied (**%HUOOcc**) and renter-occupied (**%HURocc**). The census does not provide population counts in these households, but it is possible to estimate the number of residents of each type, e.g. apply the household occupancy type (owner- or renter-occupied) percentage to the appropriate geographic unit's general population or multiply the number of households in an occupancy type by 2.5, a commonly used arithmetic average for household size. In the current instance, the number of renters (**# Renters**) in Table 1 is the mid-point between estimates calculated using both these techniques. (This estimate was applied only to the 18 Metropolitan Statistical Areas (**MSA**) in Florida, relatively large population aggregates, to avoid small area estimation errors.)

The relevance of examining these data by MSA is the concentration of households and population groups in larger numbers and more densely populated areas. Metropolitan areas are known to contain higher numbers and proportions of families at risk because of lower household income, greater difficulties in transportation (evacuation) and communication (expanse, multiple languages), and other factors that increase social vulnerability in general and vulnerability to natural hazards in particular. This examination further classified each county as having **shorelines (Gulf or Atlantic) or not** for the obvious purpose of differentiating **levels of exposure** to hurricane effects.

As shown in Table 3, the 2000 census reported 6,337,929 occupied households for the State of Florida. Seventy percent (70%) or 4,441,799 were owner-occupied households with the remainder (30%) or 1,896,130 were renter-occupied households.

As shown in Table 1, the great majority, (95% or 1,802,171 of 1,896,130), of Florida occupied rental housing units are in 34 counties in 18 MSAs**.** The percentage of household units that are renter-occupied (%HURocc) ranges by MSA from 16% in the smallest Florida MSA (Punta Gorda, a single county (Charlotte)) to 45% in the Gainesville MSA (a single county MSA that has a housing market dominated by the students at the University of Florida). Notable among other metropolitan counties with high percentages of households that are renter-occupied are Leon (43%, also dominated by student renters), and several larger metro counties (Miami-Dade - 42%; Hillsborough – 36%; Orange – 39%; Duval – 37%), three of which also have shorelines.

When the estimates were calculated for the numbers of people that these rental households represent, the differences in percentage of households that were renter occupied (31% for the combined metropolitan counties and only 21% for the combined non-metropolitan counties) produced some rather large and somewhat startling results. As shown in Table 1, there are an estimated 4.5 million (4,534,630) Floridians living as renters in metropolitan counties, but fewer than one-quarter million (239,107) living as renters in non-metropolitan counties.

Table 2 summarizes the occupied household data for 24 metropolitan counties that have Gulf or Atlantic shorelines. It reveals that 75% (1,424,444 of 1,896,130) of the renter occupied households are in these counties that are more exposed to hurricane hazards and that are apt to present additional factors that increase vulnerability.

Table 1. Renter Occupied Housing Units & Est. Pop. Renting in Florida, Metro & Non-Metro Areas

	Metropolitan Areas Counties	# ROccHU	%HUROcc	# Renters *
1	**Palm Beach-Broward-Miami-Dade MSA**	**647,293**	**0.34**	**1,659,691**
	*Miami-Dade	327,449	0.42	
	*Broward	199,695	0.31	
	*Palm Beach	120,149	0.25	
2	**Tampa-St. Petersburg-Clearwater MSA**	**294,942**	**0.29**	**718,756**
	*Hillsborough	140,362	0.36	
	*Pinellas	121,102	0.29	
	*Pasco	26,023	0.18	
	*Hernando	7,455	0.14	
3	**Orlando MSA**	**210,752**	**0.34**	**540,606**
	Orange	132,091	0.39	
	Osceola	19,672	0.32	
	Seminole	42,623	0.31	
	Lake	16,366	0.19	
4	**Jacksonville MSA**	**139,123**	**0.33**	**353,778**
	*Duval	112,013	0.37	
	*St. Johns	11,728	0.24	
	Clay	11,125	0.22	
	*Nassau	4,257	0.19	
5	**Sarasota-Bradenton MSA**	**60,919**	**0.23**	**144,632**
	*Manatee	29,513	0.26	
	*Sarasota	31,406	0.21	
6	**Melbourne-Titusville-Palm Bay MSA**			
	*Brevard	**50,310**	**0.25**	**123,331**
7	**Lakeland-Winter Haven MSA**			
	Polk	**49,844**	**0.27**	**126,719**
8	**Daytona Beach MSA**	**49,063**	**0.24**	**120,054**
	*Volusia	45,665	0.25	
	*Flagler	3,398	0.16	
9	**Tallahassee MSA**	**45,010**	**0.40**	**113,240**
	Leon	41,515	0.43	
	Gadsden	3,495	0.22	

10	**Pensacola MSA**	**44,961**	**0.29**	**116,039**
	***Escambia**	36,362	**0.33**	
	***Santa Rosa**	8,599	**0.20**	
11	**Fort Myers-Cape Coral MSA**			
	***Lee**	**44,354**	**0.24**	**107,286**
12	**Gainesville MSA**			
	Alachua	**39,424**	**0.45**	**98,565**
13	**Fort Pierce-Port St. Lucie MSA**	**28,055**	**0.21**	**68,957**
	***St. Lucie**	16,903	**0.22**	
	***Martin**	11,152	**0.20**	
14	**Naples MSA**			
	***Collier**	**25,148**	**0.24**	**62,131**
15	**Fort Walton Beach MSA**			
	***Okaloosa**	**22,274**	**0.34**	**56,496**
16	**Ocala MSA**			
	Marion	**21,572**	**0.20**	**53,125**
17	**Panama City MSA**			
	***Bay**	**18,710**	**0.31**	**46,653**
18	**Punta Gorda MSA**			
	***Charlotte**	**10,417**	**0.16**	**24,572**
	Combined Metropolitan Areas	**1,802,171**	**0.31**	**4,534,630**
	All Non-Metropolitan Areas	**93,959**	**0.21**	**239,107**
	Statewide	**1,896,130**	**0.30**	**4,773,736**
***** **(est. = midpoint of 2 estimates (%HUROcc = % of gen. pop. in rental housing & 2.5 X # of ROccHU)**				
30% (1,896,130) of Florida occupied housing units statewide are rented (U.S. Census).				
95% (1,802,171) of Florida occupied rental housing units are in 18 MSAs (U.S. Census).				

Table 2. Occupied Housing Units: County Ranking by Combined Ranks (Total Units, % Renter Occupied Units) for Metropolitan Counties That Have Gulf or Atlantic Shorelines

Comb Rank	County	TotOccHU	# OOccHU	% HUOOcc	# ROccHU	% HUROcc
1	**Miami-Dade**	776,774	449,325	57.8	327,449	42.2
3	**Hillsborough**	391,357	250,995	64.1	140,362	35.9
4	**Duval**	303,747	191,734	63.1	112,013	36.9
5	**Broward**	654,445	454,750	69.5	199,695	30.5
6	**Pinellas**	414,968	293,866	70.8	121,102	29.2
9	**Palm Beach**	474,175	354,026	74.7	120,149	25.3
10	**Escambia**	111,049	74,687	67.3	36,362	32.7
12	**Brevard**	198,195	147,885	74.6	50,310	25.4
14	**Okaloosa**	66,269	43,995	66.4	22,274	33.6
15	**Manatee**	112,460	82,947	73.8	29,513	26.2
17	**Volusia**	184,723	139,058	75.3	45,665	24.7

18	Lee	188,599	144,245	76.5	44,354	23.5
19	Bay	59,597	40,887	68.6	18,710	31.4
21	Collier	102,973	77,825	75.6	25,148	24.4
22	Sarasota	149,937	118,531	79.1	31,406	20.9
23	St. Lucie	76,933	60,030	78.0	16,903	22.0
24	St. Johns	49,614	37,886	76.4	11,728	23.6
33	Martin	55,288	44,136	79.8	11,152	20.2
34	Pasco	147,566	121,543	82.4	26,023	17.6
40	Santa Rosa	43,793	35,194	80.4	8,599	19.6
42	Charlotte	63,864	53,447	83.7	10,417	16.3
43	Nassau	21,980	17,723	80.6	4,257	19.4
49	Hernando	55,425	47,970	86.5	7,455	13.5
52	Flagler	21,294	17,896	84.0	3,398	16.0
	Subtotal	**4,725,025**	**3,300,581**	**69.8**	**1,424,444**	**30.1**
	% of State	**74.5**	**74.3**		**75.1**	

Table 3. Occupied Housing Units: County Ranking by Combined Ranks (Total Units, % Renter Occupied Units) for 67 Florida Counties (Metropolitan, Non-Metropolitan, and * Having Gulf or Atlantic Shorelines)

Occupied Housing Units: County Ranking by Combined Ranks (Total Units, % Renter Occupied Units)						
Comb Rank	**County**	**TotOccHU**	**# OOccHU**	**% HUOOcc**	**# ROccHU**	**% HUROcc**
1	*Miami-Dade	776,774	449,325	57.8	327,449	42.2
2	Orange	336,286	204,195	60.7	132,091	39.3
3	*Hillsborough	391,357	250,995	64.1	140,362	35.9
4	*Duval	303,747	191,734	63.1	112,013	36.9
5	*Broward	654,445	454,750	69.5	199,695	30.5
6	*Pinellas	414,968	293,866	70.8	121,102	29.2
7	Leon	96,521	55,006	57.0	41,515	43.0
8	Alachua	87,509	48,085	54.9	39,424	45.1
9	*Palm Beach	474,175	354,026	74.7	120,149	25.3
10	*Escambia	111,049	74,687	67.3	36,362	32.7
11	Polk	187,233	137,389	73.4	49,844	26.6
12	*Brevard	198,195	147,885	74.6	50,310	25.4
13	Seminole	139,572	96,949	69.5	42,623	30.5
14	*Okaloosa	66,269	43,995	66.4	22,274	33.6
15	*Manatee	112,460	82,947	73.8	29,513	26.2
16	Osceola	60,977	41,305	67.7	19,672	32.3
17	*Volusia	184,723	139,058	75.3	45,665	24.7
18	*Lee	188,599	144,245	76.5	44,354	23.5
19	*Bay	59,597	40,887	68.6	18,710	31.4
20	*Monroe	35,086	21,893	62.4	13,193	37.6
21	*Collier	102,973	77,825	75.6	25,148	24.4

22	***Sarasota**	149,937	118,531	79.1	31,406	20.9
23	***St. Lucie**	76,933	60,030	78.0	16,903	22.0
24	***St. Johns**	49,614	37,886	76.4	11,728	23.6
25	**Marion**	106,755	85,183	79.8	21,572	20.2
26	**Clay**	50,243	39,118	77.9	11,125	22.1
27	Hendry	10,850	7,860	72.4	2,990	27.6
28	*Indian River	49,137	38,115	77.6	11,022	22.4
29	Columbia	20,925	16,146	77.2	4,779	22.8
30	Hardee	8,166	5,997	73.4	2,169	26.6
31	Okeechobee	12,593	9,420	74.8	3,173	25.2
32	DeSoto	10,746	8,032	74.7	2,714	25.3
33	***Martin**	55,288	44,136	79.8	11,152	20.2
34	***Pasco**	147,566	121,543	82.4	26,023	17.6
35	Jackson	16,620	12,947	77.9	3,673	22.1
36	**Lake**	88,413	72,047	81.5	16,366	18.5
37	Highlands	37,471	29,853	79.7	7,618	20.3
38	**Gadsden**	15,867	12,372	78.0	3,495	22.0
39	Walton	16,548	13,075	79.0	3,473	21.0
40	***Santa Rosa**	43,793	35,194	80.4	8,599	19.6
41	Putnam	27,839	22,269	80.0	5,570	20.0
42	***Charlotte**	63,864	53,447	83.7	10,417	16.3
43	***Nassau**	21,980	17,723	80.6	4,257	19.4
44	Union	3,367	2,513	74.6	854	25.4
45	Bradford	8,497	6,709	79.0	1,788	21.0
46	Hamilton	4,161	3,220	77.4	941	22.6
47	Madison	6,629	5,194	78.4	1,435	21.6
48	*Citrus	52,634	45,041	85.6	7,593	14.4
49	***Hernando**	55,425	47,970	86.5	7,455	13.5
50	Suwannee	13,460	10,892	80.9	2,568	19.1
51	*Taylor	7,176	5,725	79.8	1,451	20.2
52	***Flagler**	21,294	17,896	84.0	3,398	16.0
53	*Franklin	4,096	3,246	79.2	850	20.8
54	*Levy	13,867	11,591	83.6	2,276	16.4
55	Baker	7,043	5,722	81.2	1,321	18.8
56	Calhoun	4,468	3,583	80.2	885	19.8
57	Sumter	20,779	17,972	86.5	2,807	13.5
58	Holmes	6,921	5,639	81.5	1,282	18.5
59	Washington	7,931	6,493	81.9	1,438	18.1
60	*Gulf	4,931	3,996	81.0	935	19.0
61	*Jefferson	4,695	3,796	80.9	899	19.1
62	*Wakulla	8,450	7,111	84.2	1,339	15.8
63	Lafayette	2,142	1,726	80.6	416	19.4
64	Glades	3,852	3,146	81.7	706	18.3
65	*Dixie	5,205	4,498	86.4	707	13.6

66	Gilchrist	5,021	4,331	86.3	690	13.7
67	Liberty	2,222	1,818	81.8	404	18.2
		6,337,929	**4,441,799**	**0.70**	**1,896,130**	**0.30**

These data support Dr. Peacock's recommendation that research be conducted to identify issues of knowledge, attitude, willingness and ability to respond to hurricane mitigation incentive programs and the nature of incentive programs most likely to be effective for owners of commercial residential (rental) property, and renters in both single and multi-family buildings.

In fact, the IHRC LSSR and FIU IPOR have proposed such survey research for the coming year under the ongoing applied research series that includes the current report. In addition, we propose that especially vulnerable populations – the elderly and households with members who are ill, especially heads of household who are physically challenged -within both the home owner and renter groups be identified in such surveys to ascertain possible impediments to mitigation activities arising from their conditions.

VI. APPENDICES

Appendix A

Homeowners Incentive Team (HIT) 1999 Recommendations

A. Building Permit Fee Reduction (City or County Legislative Action)

1. Benefit Description

Building permit authorities offer permits for mitigation retrofit projects at reduced or no fee.

2. Rationale for Benefit

Reducing or eliminating another cost of strengthening homes against hurricanes adds to the inducement to take the mitigation measures that are needed to develop a hurricane-resistant community. It is in the interest of the local community to have as many homes as possible survive a hurricane with little or no damage.

3. Factors Against Benefit

Loss of revenue to the local taxing authority is the major drawback for this incentive. Also this benefit could add to the building permit review workload, because of the added determination of qualification for the reduced or eliminated fee.

4. Impediments to Implementation

There are no statutory impediments to this incentive. An education and marketing program will be necessary to obtain commitments by local authorities. Local authorities will have to amend their building permit regulations to change the fee structure.

B. Government Subsidized Home Loan Interest Rate Reduction (State)

1. Benefit Description

Provide secured and unsecured loans at reduced interest rates to homeowners who strengthen their homes against hurricanes. The reduced interest rates will be made possible through State or Federal financing of the rate buy-down, if designated funds are available for such uses.

2. Rationale for Benefit

By reducing costs of mitigation measures, homeowners will be induced to take retrofit actions or to choose to include mitigation measures in new homes during initial construction. Interest rates on loans can add significantly to the overall cost of mitigation measures, which makes this proposal one of the most significant of the proposed incentives. Programs which feature unsecured loans, such as the newly announced Fannie Mae Pilot Loan Program, would become more attractive with lower interest rates. Secured low interest loans, including home equity loans, have the added advantage that the interest paid is tax deductible to the homeowner for qualifying residences. The need for public sponsorship of the rate buy-down stems from the lack of financial cost to lenders in event of severe damage to mortgaged homes. Interest buy downs are a cost-effective use of mitigation dollars because funds are matched many times over by the homeowners' own funds. This can stretch limited resources over a much larger number of homeowners. From the government's perspective, the primary motivation is that the government incurs significant costs following a disaster. A large part of the cost of hurricane Andrew, for example, was borne by local, state, and federal governments. These include disaster relief costs, shelter, loss of tax base, clean up costs etc. Government is a key stakeholder and will benefit significantly with mitigated housing stock.

3. Factors Against Benefit

Costs to the financial sponsors of the rate buy-down are major drawbacks to this proposal versus strictly private lender financing of lower interest rates. Administration costs of certifying the specific mitigation measures add to the burden of this type of loan. However, the government investment will produce reduced government disaster costs in the future.

4. Impediments to Implementation

Statutory and regulatory actions are required. Identifying the source of funding and establishing a program for the rate buy-down financing will take legislative support and agency time. In addition, the impediments associated with lack of mitigation standards and certification outlined in the insurance reduction proposal are common to all proposals.

5. Assessment of Impediments

Given the high interest in assisting homeowners to make decisions to strengthen their homes against hurricanes and other natural disasters, plus the perceived importance to homeowners for low interest loans, the impediments are seen as easily surmounted.

C. Government Subsidized No Interest Mitigation Loan (State)

(State Issued Bond Fund Revolving Loan Program, At No Interest, To Reduce Interest Rate On Conventional Loans)

1. Benefit Description

The mitigation loans offered by private lenders will be matched dollar for dollar by funds from the state sponsored Revolving Loan Program in order to reduce the interest rates to homeowners who wish to strengthen their homes against natural disasters. The reduced interest rates would be made possible through a State Bond issue that would be paid back. Major banks would be asked to administer the State revolving loan program as part of their CRA requirement. Permitting and inspection entities would be asked to certify that the mitigation standards had been met. If homeowners choose to additionally incorporate the States Energy Efficiency Program into their loan, the overall cost of the low interest loan would be offset by the monthly utility savings.

2. Rationale for Benefit

By reducing the interest rates of mitigation loans to below market rates, homeowners will be more likely to take advantage of the program and its other incentives. Also, when they are shown that by including energy-efficient measures into the retrofit, it will not only save them dollars over the loan period, but also provide dollars to help pay the loan. Both the retro-fit and energy efficiency programs would also be encouraged in new construction. If such a low interest rate revolving loan program is not initiated, current and future interest rates could add significantly to the overall cost of mitigation measures. Programs which feature unsecured loans, such as the newly announced Fannie Mae Pilot Program, would become more attractive with substantial interest rate reduction. Secure low interest loans, including home equity loans, have the added advantage that the interest paid is tax deductible to the homeowner for qualifying residences. The need for a public sponsored rate buy-down stems from the lack of financial cost to lenders in the event of severe damage to mortgaged homes. Interest buy downs are cost effective use of mitigation dollars because funds are matched many times over by the homeowner's own funds. Additionally, the State would recoup its investment upon pay back and with reduced mitigation costs in the future.

As a start-up, it might take a $500,000,000 State Bond issue that would be matched through the private lenders to create a $1,000,000,000 revolving mitigation loan fund. With the other proposed incentives, this could be an attractive vehicle for the retrofit and energy efficiency programs.

3. Factors against Benefit

Cost to the financial sponsors of the rate buy-down could be a major drawback to this proposal versus strictly private lending financing of lower interest rates. Administrative costs of administrating the revolving loan fund as well as certifying the mitigation measures could add to the burden of this type of loan.

4. Impediments to Implementation

Statutory and regulatory actions are required. Identifying the source of the State Bond funding and establishing a program coordinated with the private lending institutions for the rate buy down revolving loan fund will take legislative support and agency time. In addition, the impediments associated with the lack of mitigation standards and certification outlined in the insurance reduction proposal are common to all proposals.

5. Assessments of Impediments

Given the high interest expressed by homeowners to make decisions to strengthen their homes against hurricanes and other natural disasters, plus the perceived importance to homeowners for low interest rate for these retro-fits, the impediments are seen as easily surmountable.

D. Insurance Reductions (State)

1. Benefit Description

Insurers offer one or more of the following benefits to homeowners who mitigate their homes:

a. Reduction in premium rates
b. Reduction in deductibles for hurricane damage.

2. Rationale For Benefit

Effective hurricane mitigation measures can reduce the risk of damage and loss of homes caused by hurricanes. The reduction in risk to the insurer can be actuarially determined by each insurance company to form the basis for a reduction in insurance premium that would otherwise be charged or reduction of deductibles for hurricanes from current levels. Since historical loss data will not be immediately available for analysis, the initial determination may need to reflect expert opinion from engineers and hurricane risk modeling. In addition to providing more equitable premium charges to homeowners that reflect the differential risk of damage, the insurance companies offering such reductions would gain in public image as providing mitigation leadership. In the case of deductible coverage for hurricane damage, the attractiveness of lower deductibles could prove to be a major incentive for homeowners to strengthen their homes.

3. Factors Against Benefit

Section 627.062 of the Florida Statutes states that "rates shall not be excessive, inadequate, or unfairly discriminatory." Each company's premium must be sufficient to pay for losses due to natural disasters. Without an adequate premium structure for unmitigated homes, the loss in revenue from offering reduced premiums to mitigated homes could be a major drawback to this proposal.

4. Impediments To Implementation

a. State regulatory approval must be obtained before changes in premiums may be implemented. In the case of reducing some deductibles, new legislation may be required. Resistance by the insurance industry in the event the industry cannot implement a satisfactory rate level for unmitigated homes could be a major impediment. For deductible reduction, additional research may be required to obtain the data needed to justify any proposed changes.

b. For the purpose of measuring the impact on expected losses for mitigated homes, both the new construction and for retrofitted existing structures, insurers will probably want to know what specific measures will constitute such a "mitigated home" before implementation. Also, when full mitigation measures have not been taken, the value of partial measures, in terms of reduction in expected loss, may need to be calculated. The existence of such information may be instrumental in encouraging insurers to implement a variety of rate incentives. Any modeling used as part of a rate filing must be sufficient to be certified by the Florida Commission on Hurricane Loss.
c. Insurers are likely to want a dependable method of certification that mitigation features have in fact been added or incorporated in "mitigated homes," to reduce the risk of fraud or lowering the rate or deductible for a home that is not properly strengthened.

5. Assessment Of Impediments

a. Deductible reduction could face a significant hurdle if it can be shown to have an expected adverse impact on the stabilization of the property insurance market. It may also be that the base premium rate may need to be satisfactory before deductible reduction can be assessed by individual insurers.
b. Description of various levels of strengthening for a home is well within current engineering grasp; however, the value of partial measures is affected by many variables. It is expected that many insurers will want to make use of modeling before a complete set of values is available for use in justification for specific rate changes for mitigated homes.

E. Property Tax Exemption (State)

1. Benefit Description

Exclude the value of mitigation measures to strengthen hurricanes from assessed value for ad valorem tax purposes until the home has been sold, thus providing an exemption to homeowners who add value to their homes through mitigation measures for as long as they own the home.

2. Rationale For Benefit

This benefit is intended to reduce the cost consequences of adding hurricane resistant features to homes either during initial construction or as retrofit actions. Currently, property appraisers must include the value of such measures in their assessments, which means that homeowners must pay additional taxes for taking the steps to strengthen their homes, an action desired by the State. This benefit would accrue only to the original homeowner for a new home or the homeowner of record for retrofit actions, and assessed value would include those features once the home is sold. In addition to the benefit to the homeowner, the community would benefit from having an increased number of strengthened residences by having a safer, more attractive, and higher-valued community.

3. Factors Against Benefit

Local taxing authorities would have to forego an increase in taxes stemming from mitigation steps until the home is sold. This does not represent a true loss in revenue, since without incentives, homeowners are not taking mitigation measures, but there would be a perception of lost revenue. Property appraisers would have an added burden of determining the added value created by the inclusion of specific mitigation measures.

4. Impediments To Implementation

Implementation would first require amending the State Constitution, which requires approval by the electorate, most likely at the next general election following legislative approval.

5. Assessment Of Impediments

While the process of amending the State Constitution should not be taken lightly, it is noted that a bill similar to this incentive proposal has already been introduced in the Florida Senate, and the

Executive Branch did not sponsor that bill. With support from the Governor matched by a widespread public education effort, amending the Constitution should be feasible.

F. Sales Tax Exemption (State)

1. Benefit Description

Exempt State and local sales taxes on specific items used to strengthen homes against hurricanes.

2. Rationale For Benefit

This benefit will reduce the cost consequences of adding hurricane resistant features to homes either during initial construction or as retrofit actions. This one-time benefit to homeowners is intended to be another incentive to reduce the cost of mitigation measures, and therefore induce homeowners to buy or build mitigated residences. Mitigation measures are seen as being both expensive and unnecessary; this benefit will reduce the material part of mitigation efforts.

3. Factors Against Benefit

The one-time benefit to homeowners is balanced by a one-time loss of tax revenue to both the State and local taxing authorities. A large part of the loss would only be a perceived loss, because without the incentives, homeowners are not making decisions to add hurricane-resistant features to their homes.

4. Impediments To Implementation

This benefit requires statutory support before it could be implemented, and would require special identification of the specific building material articles that are to be exempt.

G. Federal Tax Reduction (Federal)

1. Benefit Description

Provide for a Federal income tax reduction by allowing a deduction for the costs of specific measures taken to strengthen homes against natural disasters by homeowners who itemize deductions.

2. Rationale For Benefit

Homes and communities that are strengthened against hurricanes will experience less damage and will cause less cost to governmental agencies involved with natural disaster recovery. There is a public good for homes to be stronger and have specific features that make them less vulnerable to damage from hurricanes. This benefit to homeowners is another step in reducing the cost of their decision to strengthen their homes either through retrofit measures or during initial construction, and is similar in rationale to the tax break given for energy conservation measures.

3. Factors Against Benefit

Reduction in Federal revenue.

4. Assessment Of Impediments

Even assuming achieving sponsorship by members of Congress representing Florida and the addition of support from other states that experience other natural disasters, this proposal is likely to become part of the issue of making fundamental changes to the Federal tax structure. Debates concerning changing to a "Flat Tax" or a value-added tax are likely to inhibit changes to the existing tax structure. However, the benefits nationally of having homes more resistant to natural disasters makes it important to have this issue surfaced in the Congress before a new tax structure is adopted.

H. Brokerage Fee Reduction (Private Sector Initiative)

1. Benefit Description

Voluntary reduction in commission rates charged by real estate brokers to sellers of homes that have been strengthened to withstand hurricanes.

2. Rationale For Benefit

In general, a mitigated residence should be more desirable than a similar but non-mitigated home in the same area, especially as the public becomes more aware of specific mitigation features and their effect on resistance to hurricane damage. The greater desirability of mitigated homes has an effect on three important aspects of real estate sales:

a. Mitigated homes should sell faster than non-mitigated homes, thereby reducing the selling costs to brokers as well as the time invested in showing homes.

b. The market value for mitigated homes should be higher than that for similar non-mitigated homes. This may result in a slight increase in total commissions, which would offset the lower commission rate offered by the proposal.

c. Brokers advertising reduced commissions for mitigated homes may have the potential for increasing market share and total commission volume. Also, buyers seeking mitigated homes will be attracted to brokers who advertise that they specialize in mitigated homes, thereby increasing total brokerage commission potential.

The concept of making a special offer to a select group of people as a marketing effort to increase listings and sales is not uncommon in the real estate industry. Examples include offers for reduced brokerage commissions to senior citizens and military personnel. The difference with this proposal is that mitigated homes offer a more attractive and higher value product that should sell more quickly.

It should be noted that the real estate industry is an industry which communicates with the public at times when the public's interest in a home's features is the highest. Thus, the real estate industry can contribute significantly to public education and awareness of the importance and value of mitigation measures in home construction.

3. Factors Against Benefit

The primary negative factor is the reduction in commissions earned by brokers and agents alike for each listing and sale.

4. Impediments To Implementation

There are no statutory or regulatory impediments to implement this incentive. Brokerage commissions are set by a mutual agreement between each seller (or buyer, in the case of a buyer brokerage) and the seller's broker. It should be noted that the real estate industry would be faced with some major changes, as set fees for listing homes, in lieu of commissions based upon sale prices, would be new in some areas for some brokers.

I. Building Material Discounts (Private Sector Initiative)

1. Benefit Description

Retail level discounts offered by building material suppliers to homeowners and builders on specific items used in strengthening homes against hurricanes.

2. Rationale For Benefit

Reduction of costs of mitigation efforts might induce homeowners to build **or** retrofit their homes, and could offer the following benefits to suppliers advertising discounts or "sale prices" on selected mitigation products:

a. Increased sales in expensive mitigation products by creating a market.

b. Advertisements could attract buyers who will buy other items in addition to the mitigation items, and therefore obtain increased sales overall by bringing customers to the store.
c. Enhanced public image by reducing prices on "safety" items.
d. Improved public awareness from the public exposure that the mitigation products receive through the ads.

3. Factors Against Benefit

The major drawback to suppliers is the loss of profit offering products at a reduced markup.

4. Impediments To Implementation

There are no statutory or regulatory impediments to implementing this incentive. Starting an advertising and discount campaign should be timed with implementation of other incentives, lest retailers experience no reaction to advertisements and lose interest.

J. Employer Assistance To Employees (Private Sector Initiative)

1. Benefit Description

Employers offer to their employees benefits, in one or more of the following ways, to those employees who strengthen their homes against hurricanes:

a. A share of the cost for the retrofit or construction costs, with or without a cap.
b. A set grant for specific mitigation projects.
c. Paid leave of absence for those employees who perform the installation work themselves.

2. Rationale For Benefit

a. Employees whose homes are strengthened to survive a hurricane will be available for work during or after hurricane passage, as opposed to those employees whose homes are destroyed or severely damaged. Firms are dependent upon availability of employees to perform business functions in order to stay in business.
b. Assisting employees to strengthen their homes enhances labor relations, which leads to easier recruiting and better retention. This one-time benefit could enable an employer to hire at a lower starting salary, as a trade-off for the extra benefit. Providing for protection of one's home could be a significant if not dominant benefit offered to employees, to peace of mind and good will.
c. Employers will gain a good public image as enlightened and responsible citizens of the community.

3. Factors Against Benefit

These include:

a. Cost to the employer is the major drawback for this incentive, since the costs are up-front and the primary benefit will not be felt until experiencing a severe storm.
b. Providing this benefit may force lowering of other items in an employer’s benefit package being offered.

4. Impediments To Implementation

There are no statutory or regulatory impediments to this incentive. Budgetary constraints could delay implementation, however, especially for public agencies like municipal and county governments, who must insert new personnel benefits in budget formulation cycles well in advance of the fiscal year.

5. Assessment Of Impediments

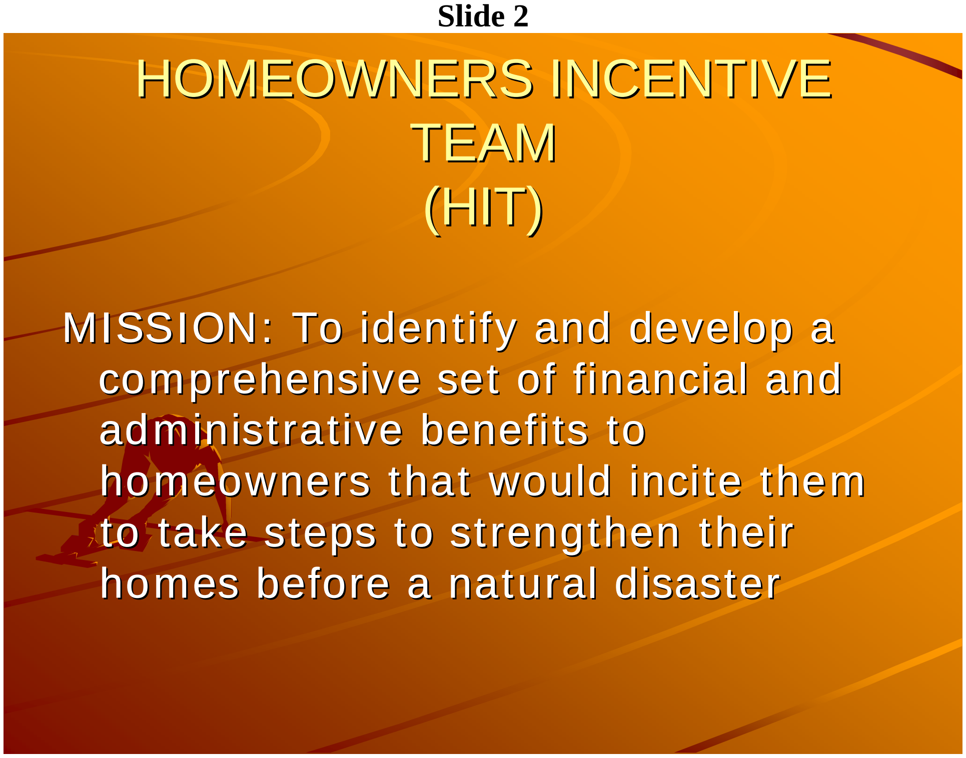
Marketing this incentive with government agencies and the public will be required to gain support for this new benefit. State leadership in establishing this benefit for public employees will reduce the time to gain acceptance of this concept in both public and private sectors.

Appendix B

HIT Recommendations Revisited
Charles McCool, Department of Community Affairs

Slide 1

Slide 2



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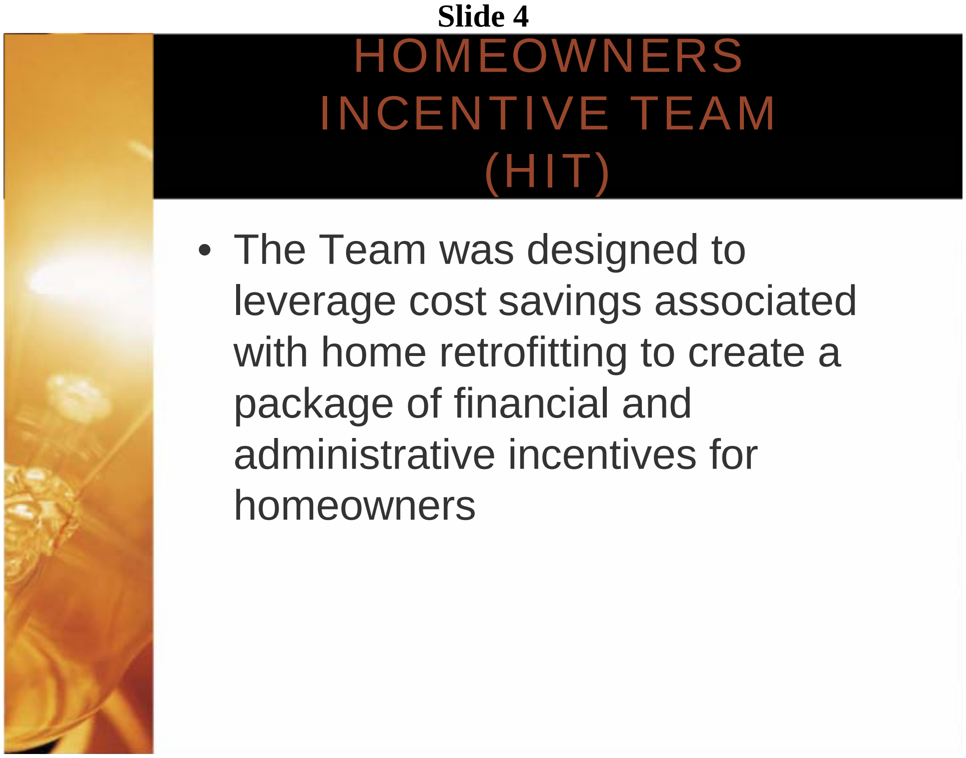

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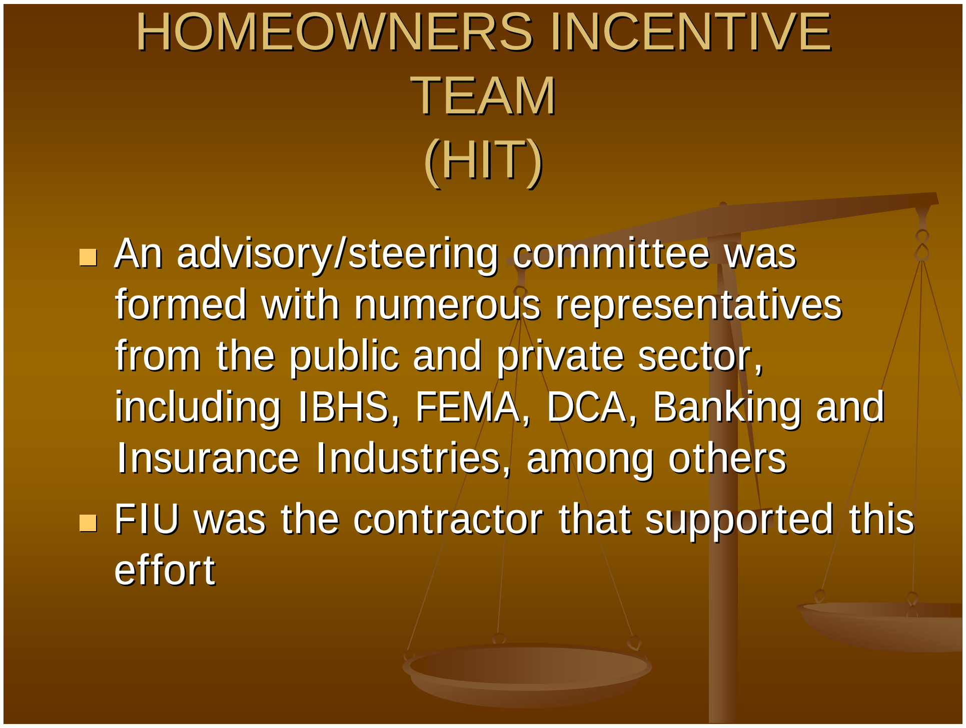

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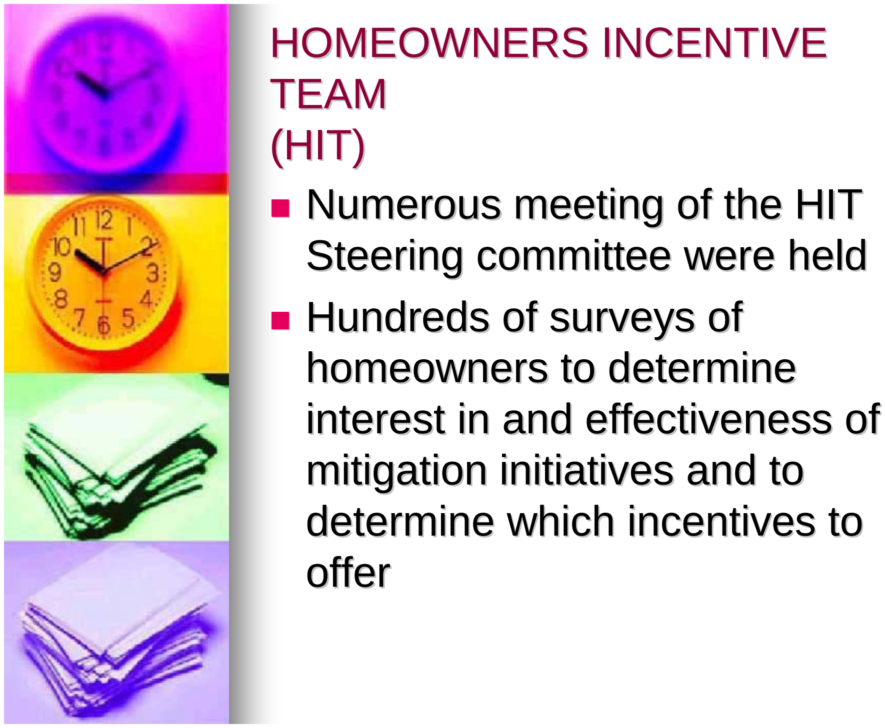

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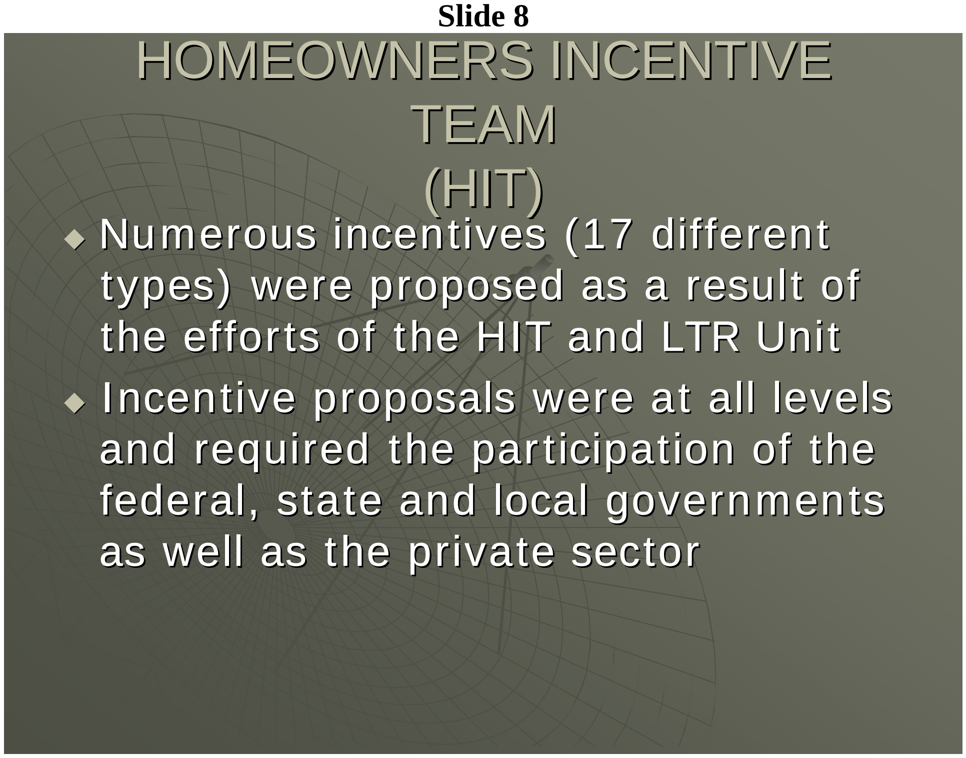

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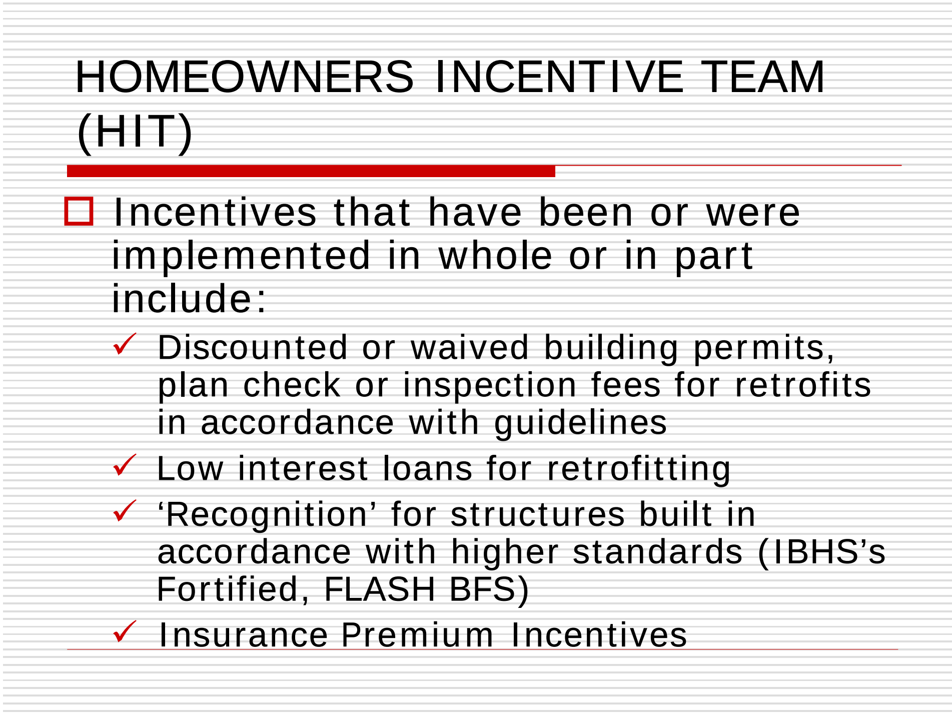

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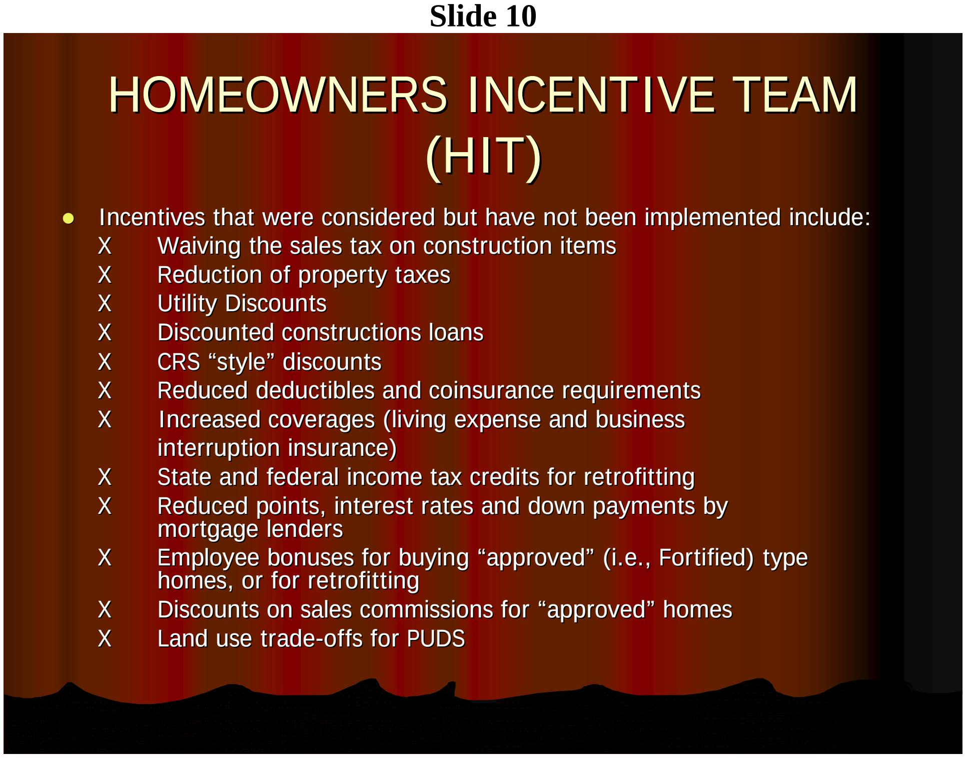
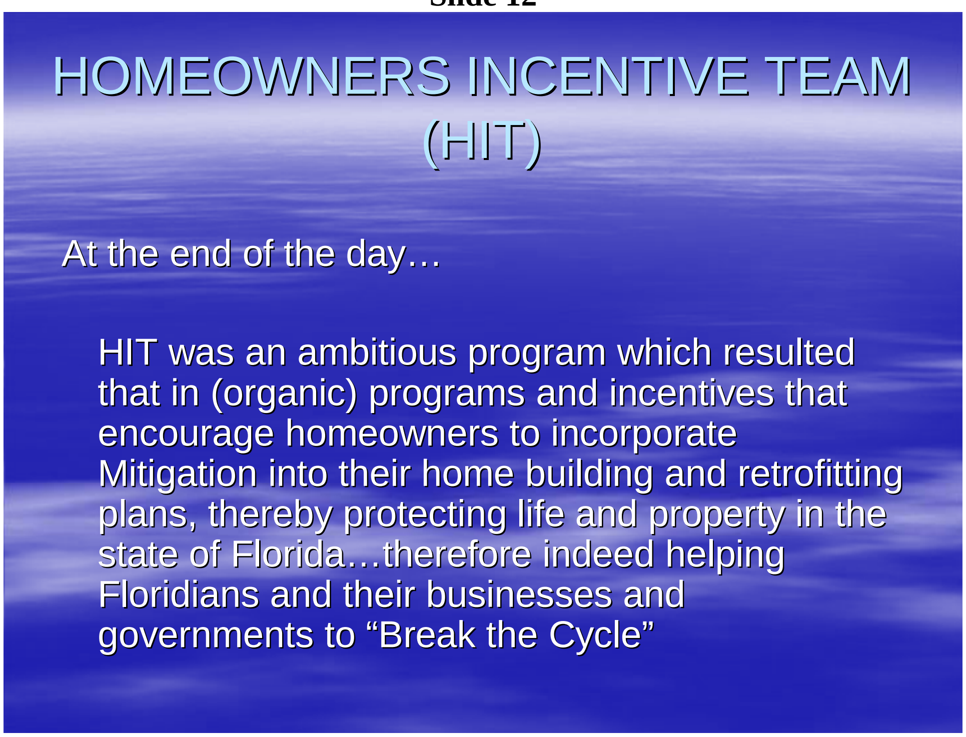


Slide 11

Slide 12



Appendix C

Florida Residential Mitigation Status and Response to Potential Mitigation Incentives: A Brief Narrative*

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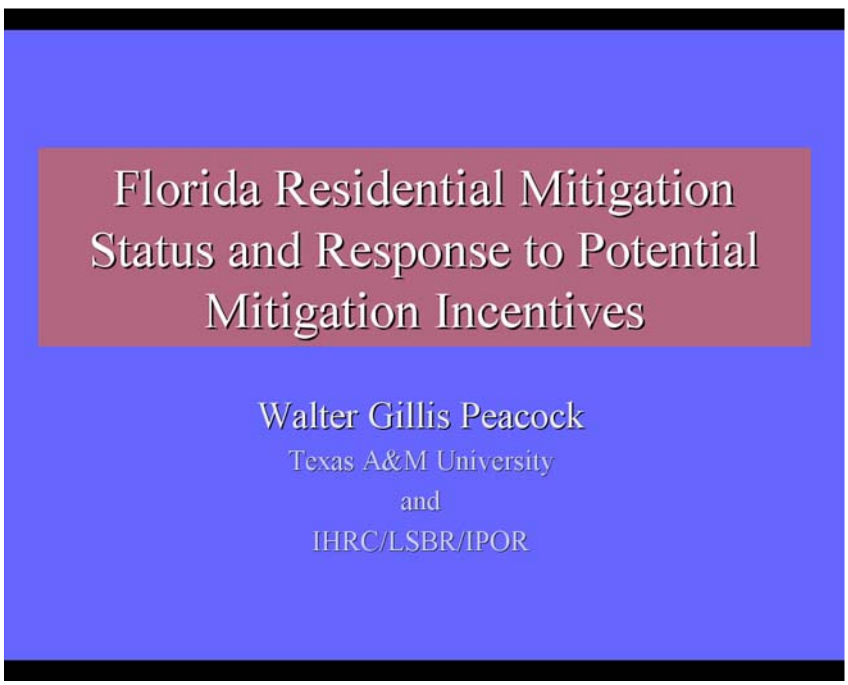

* The following is a short narrative that accompanies a detailed presentation given at the Incentives Workshop at the International Hurricane Research Center, Florida International University, Miami Florida. April 31, 2004.

Florida Residential Mitigation Status and Response to Potential Mitigation Incentives: A Brief Narrative[*]

Introduction:

Over the last number of years researchers[5] associated with the Laboratory for Social and Behavioral Research (now the Laboratory for Social Science Research) at International Hurricane Research Center and the Institute for Public Opinion Research, both of which are located at Florida International University, along with various collaborators have been involved in rather extensive research examining the degree to which Florida's single family homeowners are prepared for hurricanes. In particular, we have generally focused on hurricane preparation in the form of envelope coverage. Engineering research, much of it conducted after hurricane have damaged areas in Florida, has generally shown that if a home's envelope can be protected by properly protecting openings – windows, door-ways, and garage door openings – the much of the destructive properties of hurricane winds can be thwarted and the home's destruction prevented. This means that windows and sliding glass doors must be protected by devices such as hurricane shutters. Our research, therefore, has focused on how well protected owner-occupied single family homeowners throughout the state of Florida are and if they are not protected, are they considering getting protection for their homes.

The following will offer a brief narrative to accompany the PowerPoint slides that were presented at the Incentives Workshop that was held at the International Hurricane Research Center on April 1, 2004. The presentation was designed to discuss many of the major findings developed during this line of research. In particular, the presentation addressed four topics (see slide one): 1) what is the mitigation status of Florida's single family owner occupied homes?; 2) how responsive are those without adequate wind protection to various incentive programs that may or may not be offered by governmental or non-governmental agencies?; 3) what are the characteristics of those households that might be responsive to different types of incentive programs?; and lastly 4) what is the mitigation status of all Florida's homes? The latter question we thought was particularly important because there has been entirely too much focus on only single family owner occupied homes, that represent only a portion of all of Florida's homes. Indeed, in some metropolitan counties, there are almost as many renters as homeowners and in major cities, renters actually outnumber homeowners. Statewide, 30% of the occupied housing units are renter occupied.

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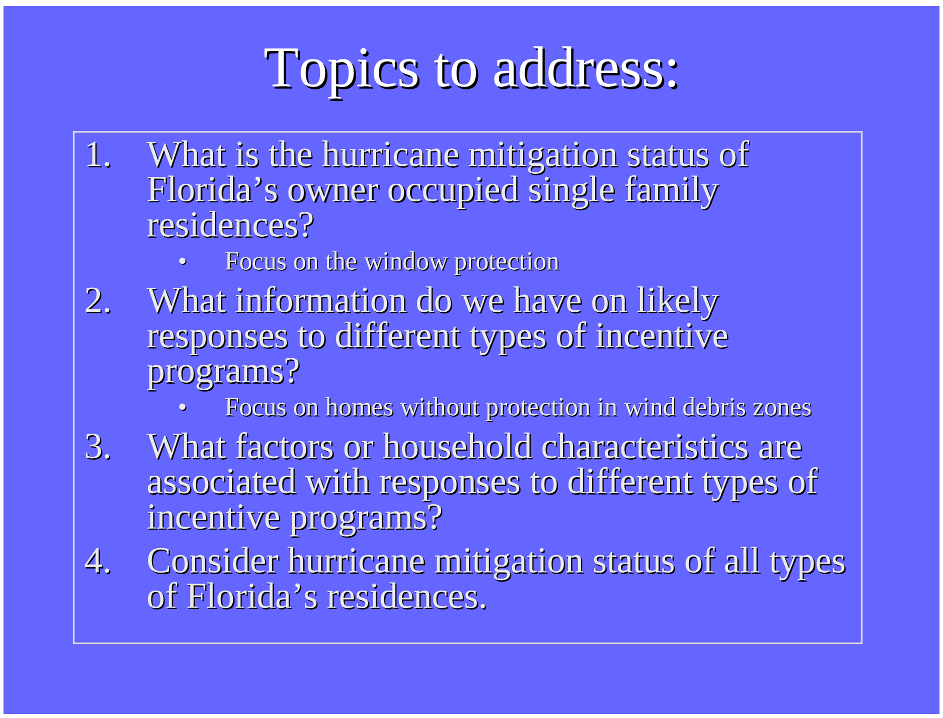
[*] The following is a short narrative that accompanies a detailed presentation given at the Incentives Workshop at the International Hurricane Research Center, Florida International University, Miami Florida. April 31, 2004.

[5] These researchers include, Walter Gillis Peacock (now with Texas A&M University), Hugh Gladwin, director of IPOR, Betty Hearn Morrow, former director of the LSBR now retired, Nichole Dash, now with the University of North Texas, and, more recently, James Rivers, current director of the LSSR. Ricardo Alverez, has also been a collaborator in these research efforts and has been a primary player focusing efforts at shaping research at the IHRC.

Hence, it is important consider how safe all of Florida's families are, not just those more affluent families and households that can afford to own their own homes. Unfortunately, there is no accurate data on all of Florida's homes when it comes to hurricane protection; therefore we will use data from Miami-Dade and Broward Counties to at least get a glimpse into this important component of Florida's homes.

To simplify our results and maximize data compatibility, our focus is on window coverage, rather than total envelope coverage. In a sense, this may introduce a bias in the analysis toward greater mitigation across all surveyed household categories than would result if all openings were considered, i.e. households that have window shutters often lack hurricane resistant garage doors and other door protection. However, the overall results, particularly with regards to incentive programs are not changed at all by this decision.

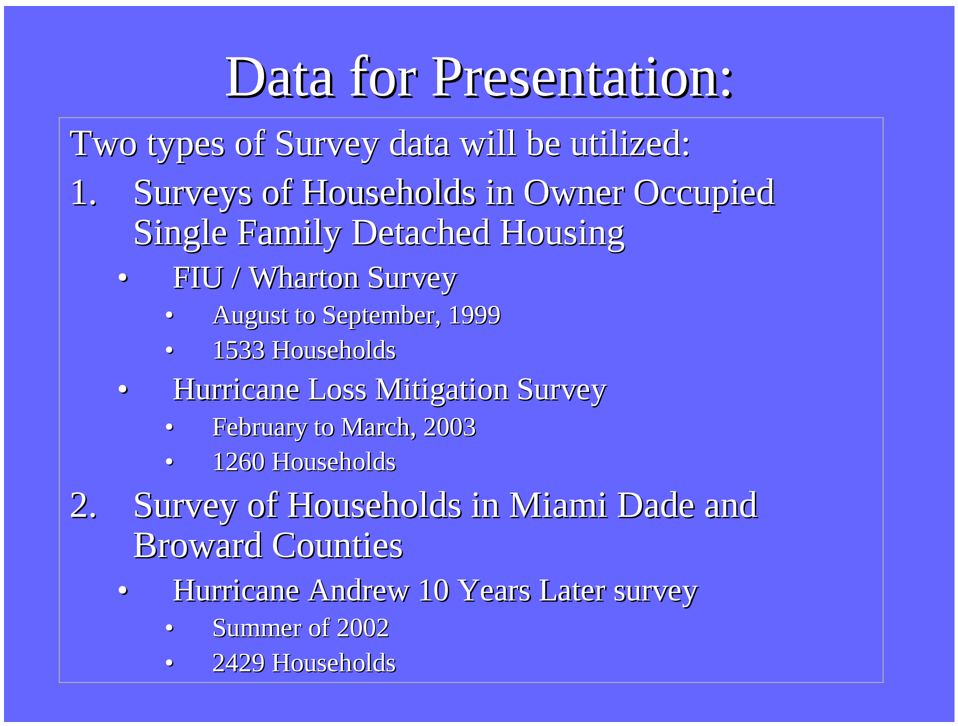
Slide 1.



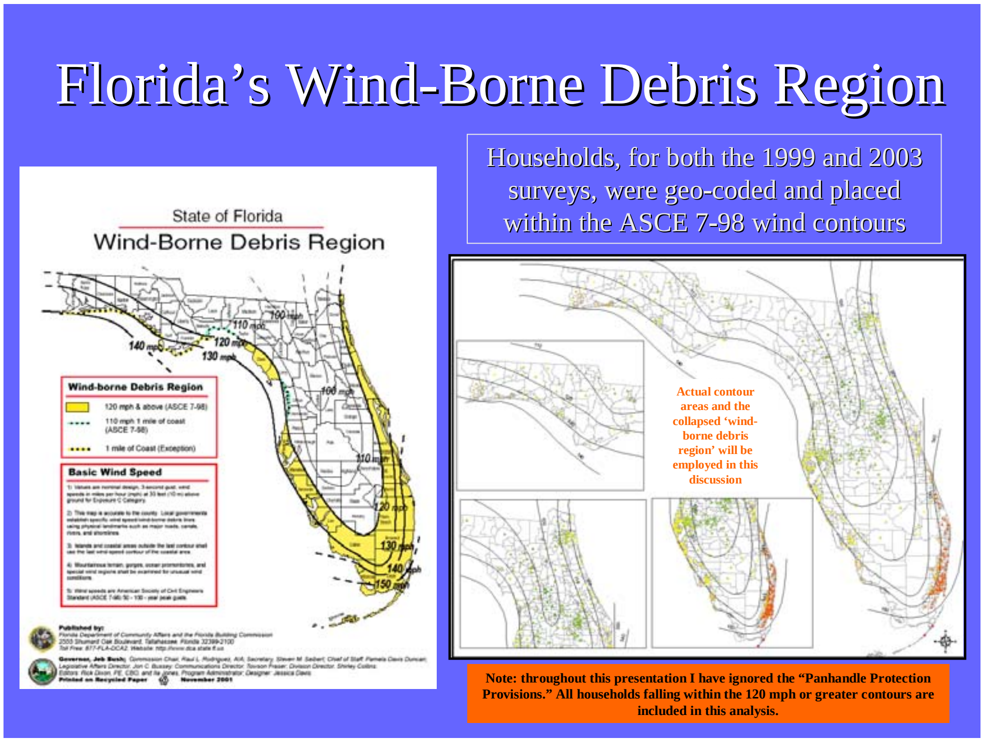
As mentioned above, we have been involved in a variety of research projects over the last few years. Some of these research projects have been statewide while others have focused on only limited regions of the State. For the purposes of this presentation data from the two most compatible statewide surveys are employed – one conducted in 1999 and the other in 2003. The information on Slide 2 provides key information regarding these two studies. In addition, data from a recent survey of all households – including those residing in single-family owner occupied homes and all forms of rental housing – in Miami-Dade and Broward households are also examined. Again, information on this survey is also provided on Slide 2 (see below).

In order to better understand the consequences of where households are located around the State for mitigation status and receptiveness to potential incentive programs, data would often be presented for different regions of the State. For example, South Florida homes might be compared to those in the Panhandle or North Florida. However, with the development of the Statewide Building Code, regions of the State have now been identified according to their probability of experiencing wind gusts of various level of magnitude or speed and certain areas have also been officially recognized as “Wind-Borne Debris” regions (see Slide 3). In order to better facilitate discussion at the workshop, respondents for both the statewide surveys were geo-coded according to their zip codes and then located in the different wind contours and ultimately into those located in wind-borne debris zones or not. Slide 3 displays the location of respondents with respect to the various wind-zones identified by the ASCE 7-98 wind contours. In subsequent analysis the results will often been presented employing these wind zones.

Slide 2.



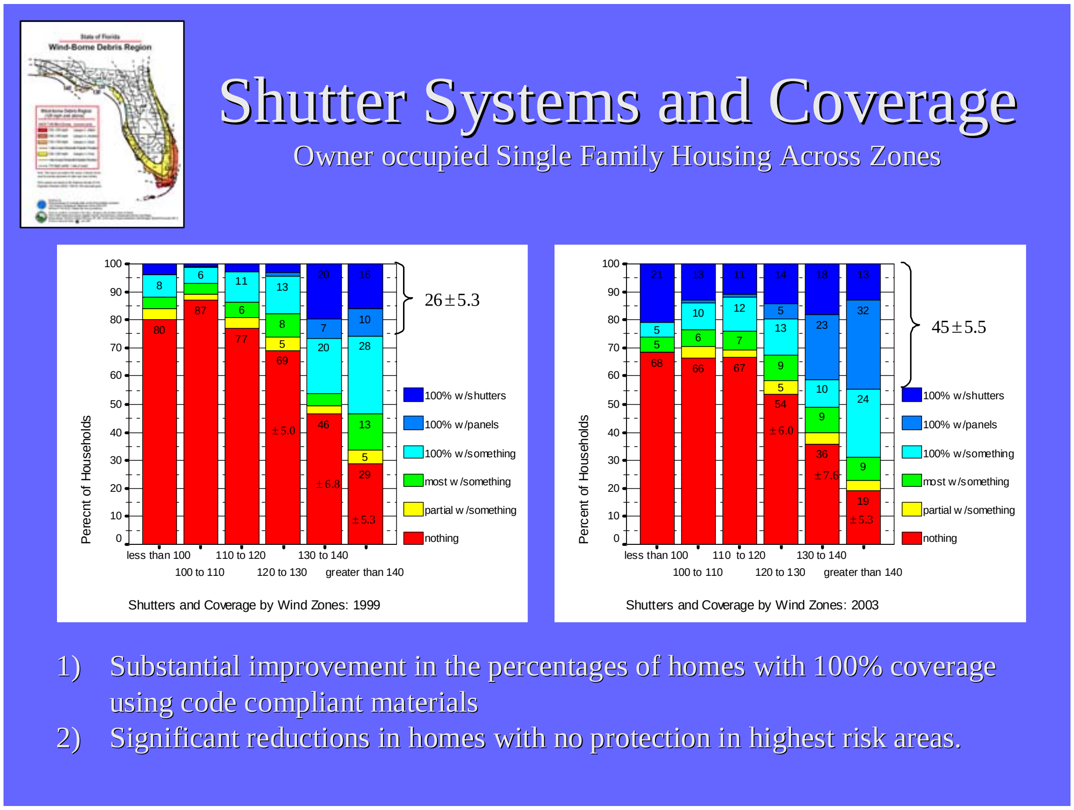
Slide 3.



Window Protection:

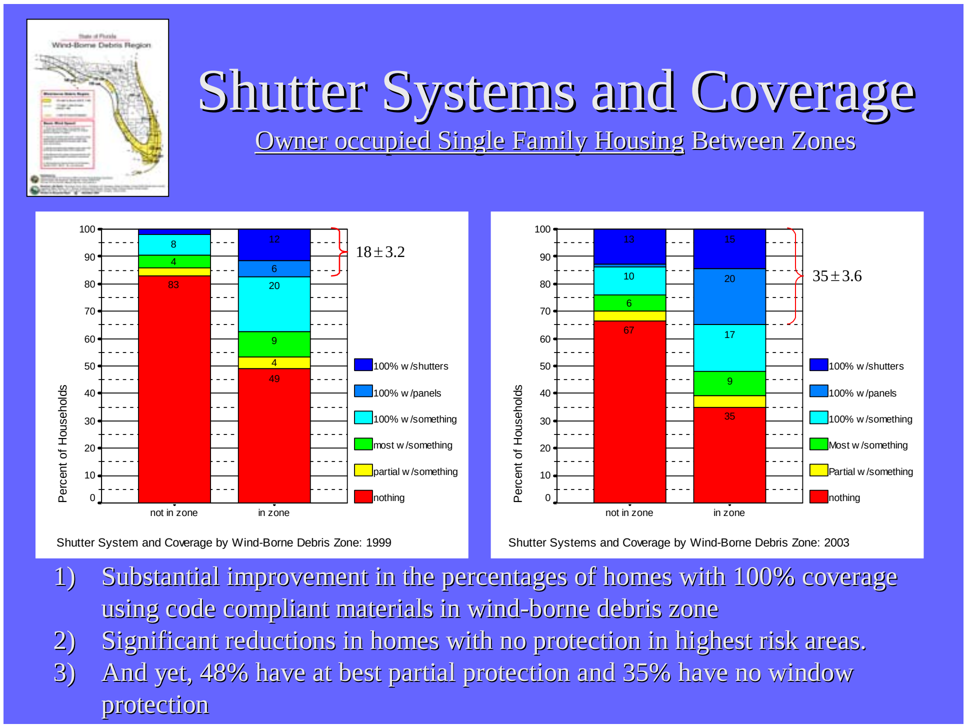
Slide 4 and 5 present data on different levels of window protection for each of the wind zones (Slide 4) and for households located in wind-borne debris zones versus those outside those zones (Slide 5). As can be seen in slide 3, all home located in wind zones subject to 120 mph gust or above are in the "wind-borne debris zone" and are now required to have window protection for new construction. Hence, by extension, there is clearly a recommendation for all homes located in this 'wind-born debris zone' to have window protection. Homes have also been classified in terms of the nature of their window protection, i.e., as hurricane panels, and whether or not they have 100% coverage or less. Homes with 'something' generally have plywood or some combination of materials that are not generally recognized by building codes as being consistent with code requirements. Hence, only those homes in the top two categories, i.e., those that have 100% coverage with hurricane shutters or panels, have the possibility of being code compliant. This does not mean that homes with 100% plywood shutters might not stand up in a hurricane, it simply means that the types of materials used are not code compliant.

Slide 4.



As can be seen in Slides 4 and 5, there has been significant improvement in the percentages of homes that are 100% covered by potentially code compliant materials as well as those that are 100% covered by any type of material between 1999 and 2003. This holds particularly well for homes that are likely to experience wind gusts over 130 mph. Unfortunately, we do not see that dramatic of improvements in home in the 120-130 mph zone. Nevertheless, on the hold, in the State's new wind-debris zone there is significant improvement. On the other hand, nearly 48% of all single family owner occupied homes have less than optimal window protection. Indeed, 35% of these homes – homes that are occupied by the more affluent households in the State of Florida, do not have any protection what so ever. There is still much to be done.

Slide 5.

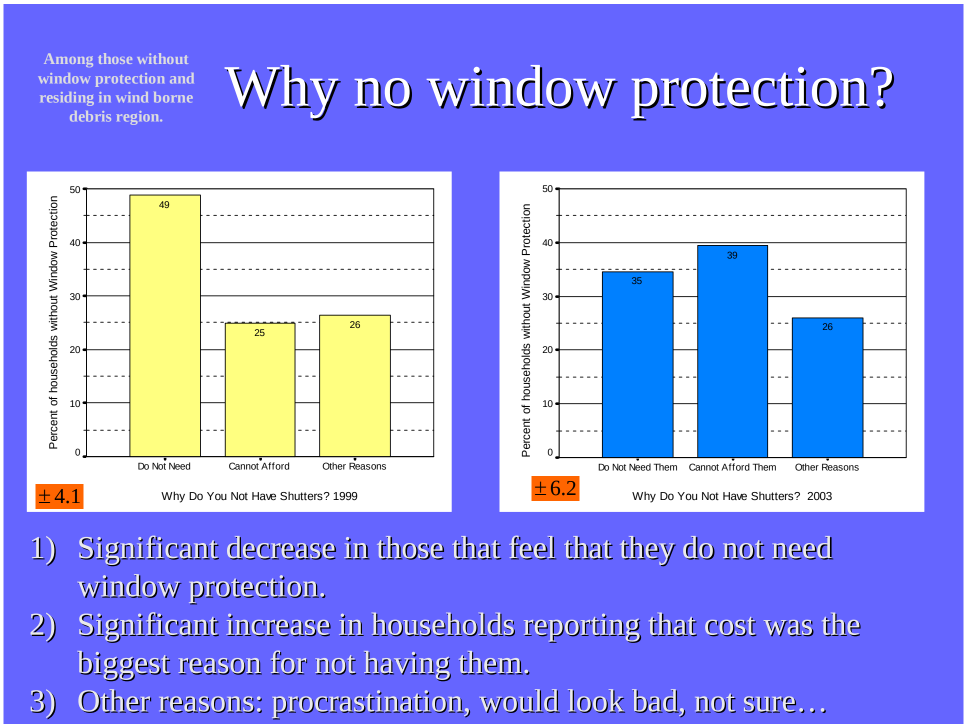


As one views these slides it is critical that you keep in mind that we are dealing with owner occupied households, not all households in Florida. These households are much more affluent, in that they have higher incomes and education levels than other households. At the end of this paper, a slide will be presented showing all households in Broward and Miami-Dade households and their window protection. For now, we are only focusing on households in owner-occupied single-family homes.

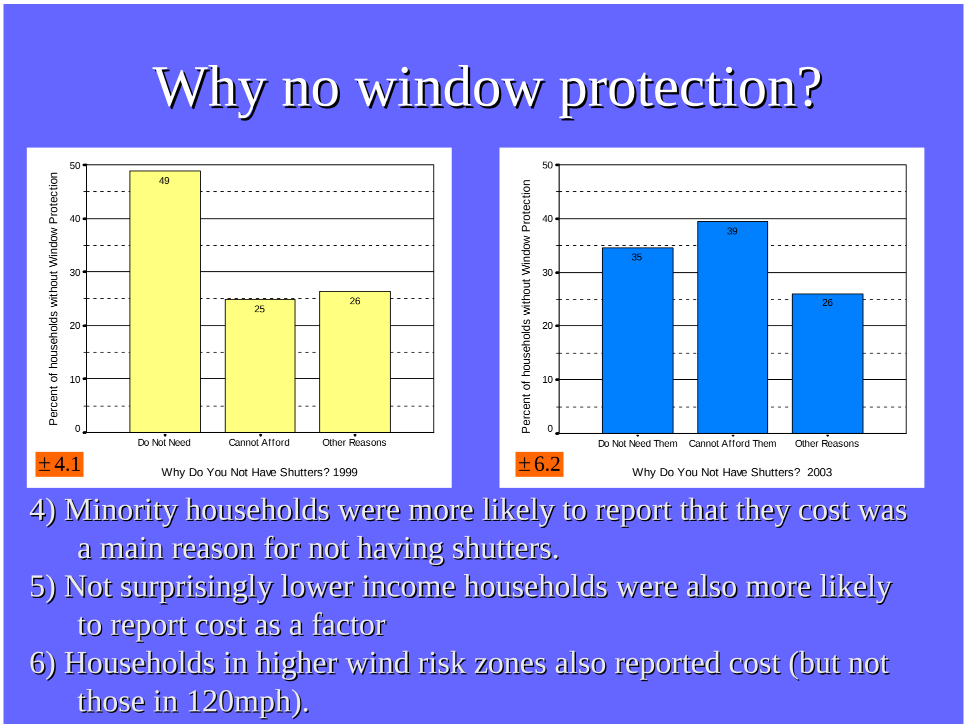
Why no or only partial window Protection?

We now turn our attention to only those households in owner-occupied single-family homes that are located in the “wind-borne debris zone” and who do not have window protection. Specifically we asked these households why they do not have window protection. The results in Slides 6 and 7 give us some of the results. The results clearly suggest there have been some changes in reasons given for why they do not have window protection. On the whole significantly fewer now say that they do not need window protection and significantly more now say that cost is a reason for them not having shutters. In light this, it should not be surprising that lower income and minority households (African American and Hispanic households) are much more likely to mention that cost is a primary factor for them not having window protection.

Slide 6.


Among those without window protection and residing in wind borne debris region.
Why no window protection?
Percent of households without Window Protection
50
40
30
20
10
0
49
25
26
Do Not Need
Cannot Afford
Other Reasons
±4.1
Why Do You Not Have Shutters? 1999
Percent of households without Window Protection
50
40
30
20
10
0
35
39
26
Do Not Need Them
Cannot Afford Them
Other Reasons
±6.2
Why Do You Not Have Shutters? 2003
1) Significant decrease in those that feel that they do not need window protection.
2) Significant increase in households reporting that cost was the biggest reason for not having them.
3) Other reasons: procrastination, would look bad, not sure…

Slide 7.

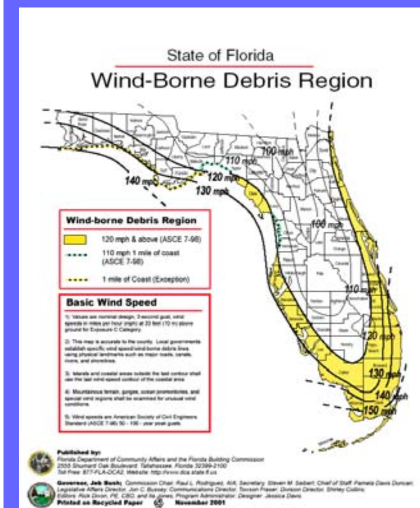


Potential Response to Incentive Programs:

As part of our surveys we always asked a variety of questions regarding various types of incentive programs and potential responsiveness to these different types of programs (See Slide 8). As is presented on Slide 8, we asked questions about low interest loans, forgivable loans, property tax reductions, insurance incentives, and inspections programs much like the Florida Power and Light energy inspection home that provides homeowners with vouchers that can be use to increase the energy efficiency of their home. Slides 9 – 12 present the results from these questions along with additional discussion of each. It must be pointed out again, that these results are only for households residing in the wind-borne debris zone and who do not have shutters.

Slide 8.

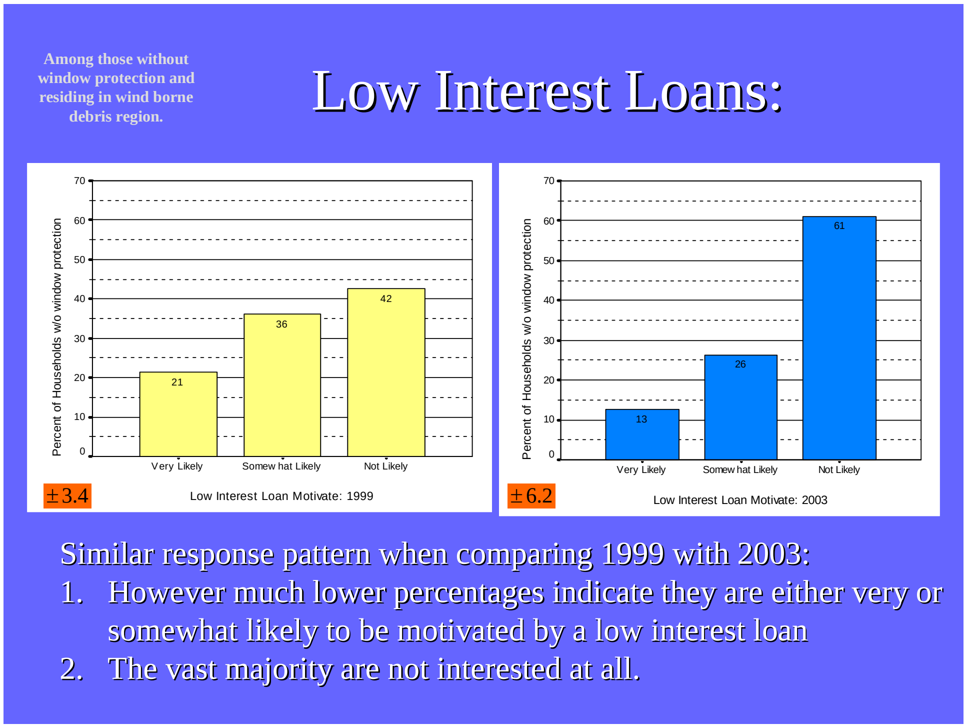
Response to potential Incentives



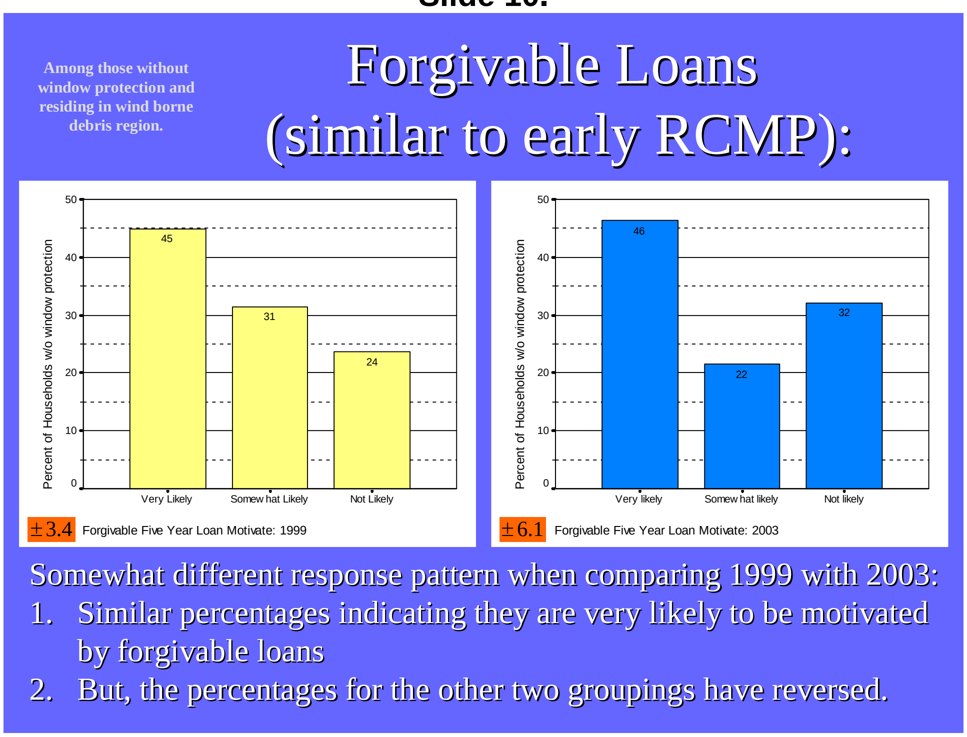
- Low interest Loans
- Forgivable Loans
- Property Tax Reductions
- Insurance Incentives
- Inspection programs with mitigation credits

Our focus, again, is on single family owner occupied homes without shutters residing in ASCE 7-98 contours in excess of 120 mph.

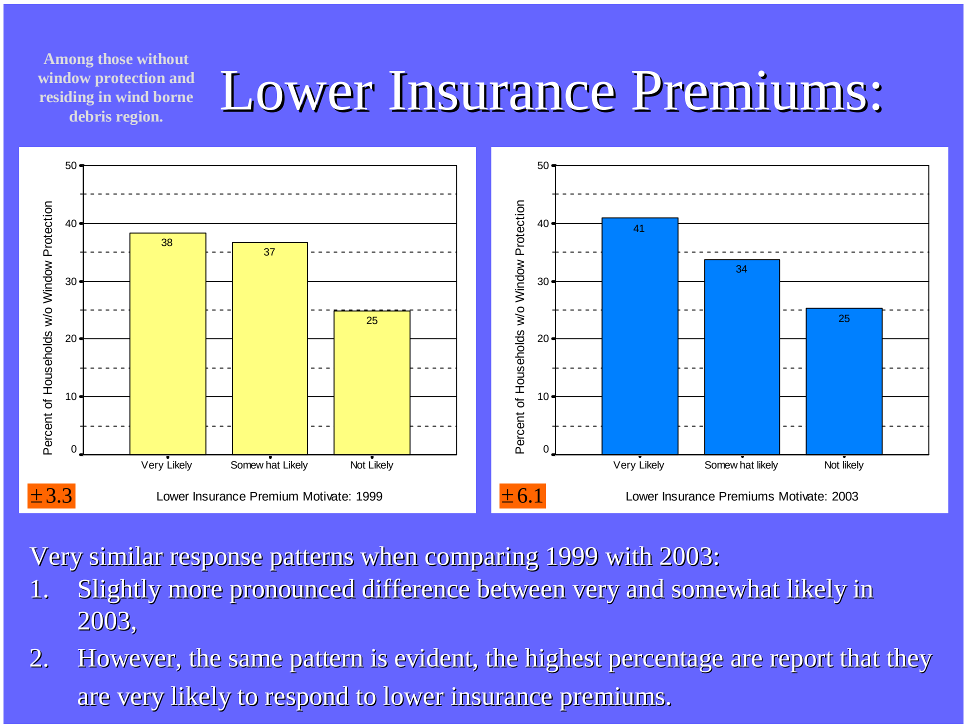
Slide 9.



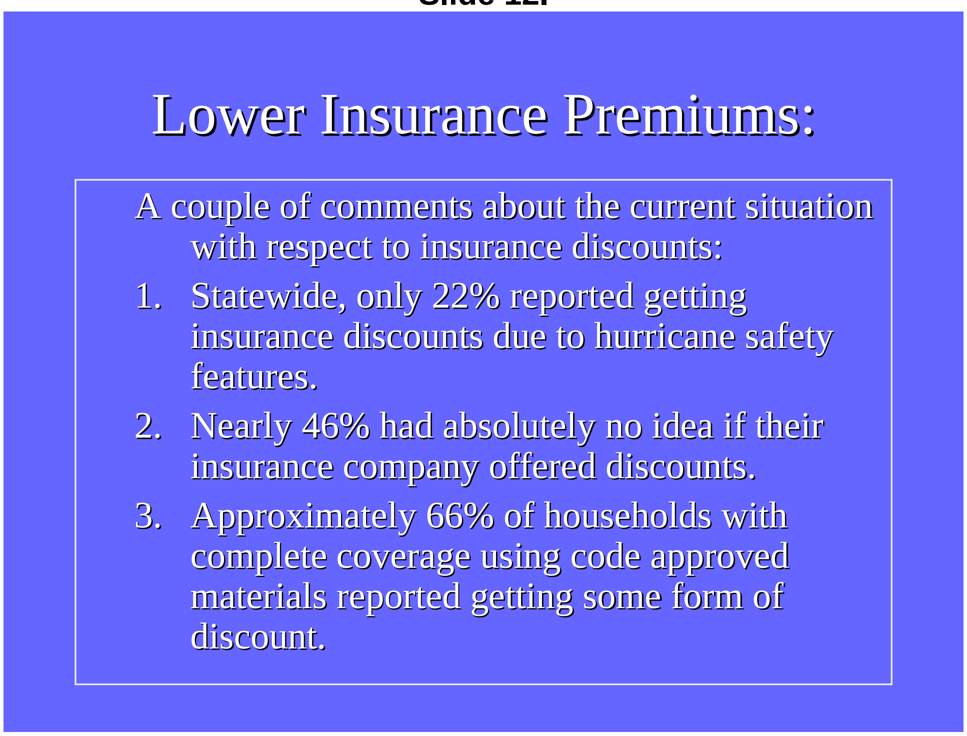
Slide 10.



Slide 11.



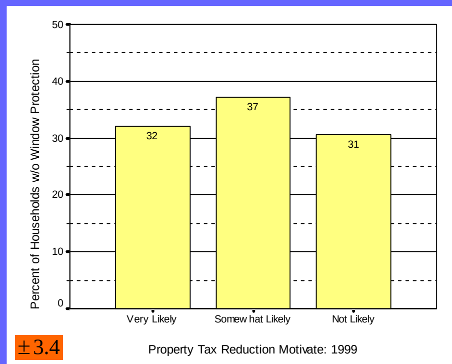
Slide 12.

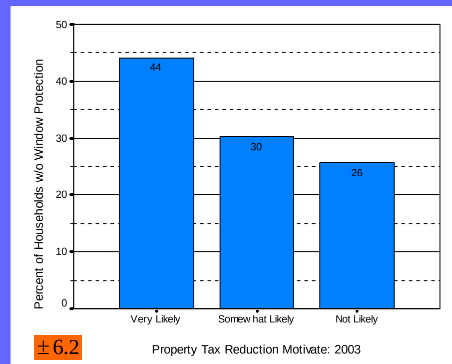


Slide 13.

Among those without window protection and residing in wind borne debris region.

Property Tax Reductions:





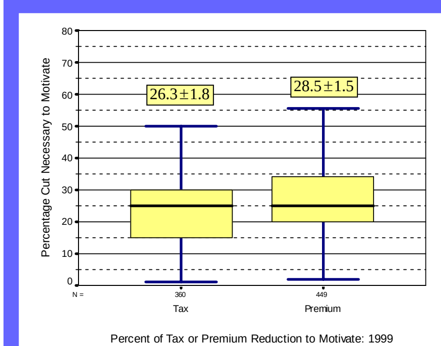
Different response patterns emerge when comparing 1999 with 2003:

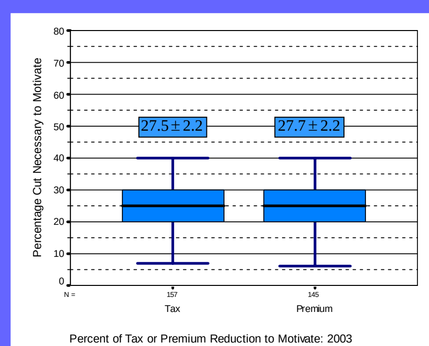
1. The 'somewhat likely' response is dominant in 1999 at 37%, with the other responses hovering between 31 and 32%.
2. In 2003 however, the 'very likely' response is pronouncedly dominate at 44%, with 30% responding "somewhat likely" and 26% responding "not likely." premiums.

Slide 14.

Among those without window protection and residing in wind borne debris region.

How large property taxes and insurance premium reduction?

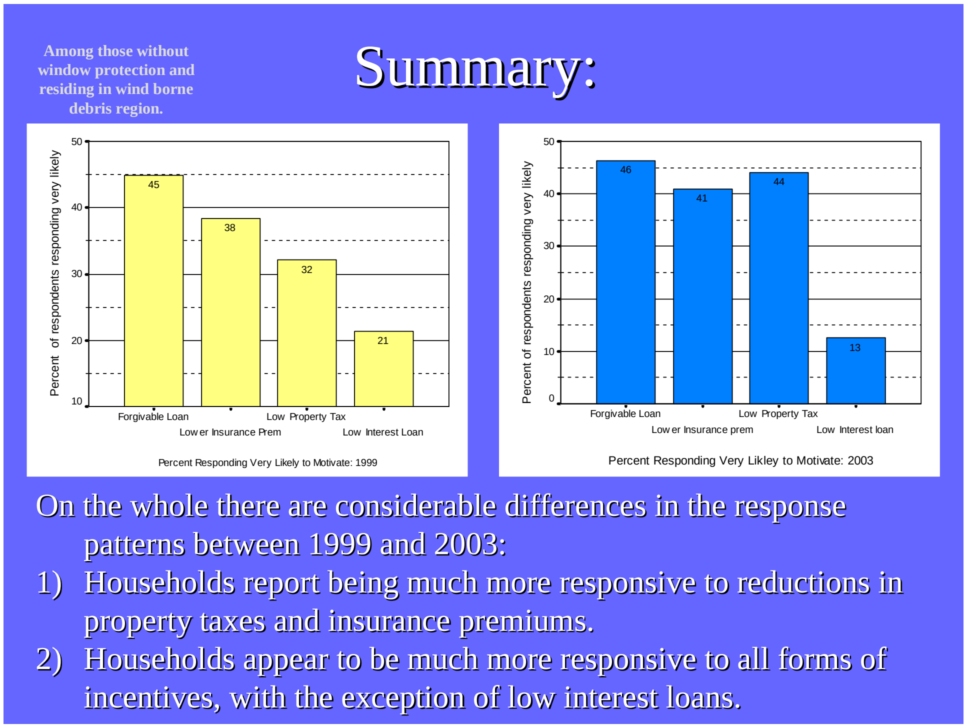




Findings are remarkably similar when comparing both 1999 and 2003 results and when comparing tax and premium reductions.

1. The median tax and premium reductions are 25% with mean values hovering between 27 and 28%.
2. On the whole the values are highly positively skewed (not reflected in the plots), hence the median values might be most appropriate.

Slide 15.



On the whole, there are considerable differences in the response patterns between 1999 and 2003. Of course, a primary reason is that we are probably looking at very different types of households. Between 1999 and 2003, households have experienced more hurricane threats, particularly Hurricane Floyd, a massive hurricane that slid along the entire east coast of Florida, prompting one of the largest hurricane evacuations the state have ever experienced and hopefully Florida's residents are much more aware of their hurricane risk. It is likely that many households that could afford shutters may have gotten them between 1999 and 2003. The point is that many of the households we are looking at in 2003, may want shutters, but just simply can't afford them, as we saw in Slide 7, or there may be other reasons holding them back. Regardless, on the whole, households that do not have shutters and reside in Florida's wind-borne debris zone are much more responsive to all incentive programs, other than low interest loans, and they certainly report being more responsive to tax and insurance incentives. Recent changes in requirements for insurers to offer incentives, may well help this picture considerably, particularly given the large number of respondents that have no clue if their insurers offer such incentives (see Slide 12). But what is equally clear is that the levels of insurance reductions (or tax cuts for that matter) necessary to be an incentive are far beyond realistic levels (see Slide 14). It is therefore incumbent upon the State and local governments to seek to stimulate alternatives, creating a portfolio of incentives that together might induce or at least make it possible for all single-family homeowners to more adequately protect their homes.

To better understand what types of households will respond to different types of incentives additional analysis was undertaken with using the 2003 data. Slides 16 and 17 discuss how these analyses were carried out and Slides 18 and 19 provide the findings.

Slide 16.

What types of households respond to different incentives

- This analysis was undertaken first by examining bivariate relationships:
  - Examining cross-tabulations between each type of incentive and various household characteristics
  - Characteristics included: income, race, years in residence, location relative to wind contours, hurricane experience (experience and experience damage), and age composition (elders, elder households, young children).

Slide 17.

What types of households respond to different incentives

- This analysis was also undertaken using various multivariate models:
  - In each case, multivariate models were developed to predict how households respond to potential incentive programs.
    - $Link(\gamma_i) = \theta_j - [\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k]$
  - Characteristics included: income, race, years in residence, perceptions of hurricane risk, hurricane knowledge, location relative to wind contours, hurricane experience (experience and experience damage), and age composition (elders, elder households, young children).

Slide 18.

What types of households respond to different incentives

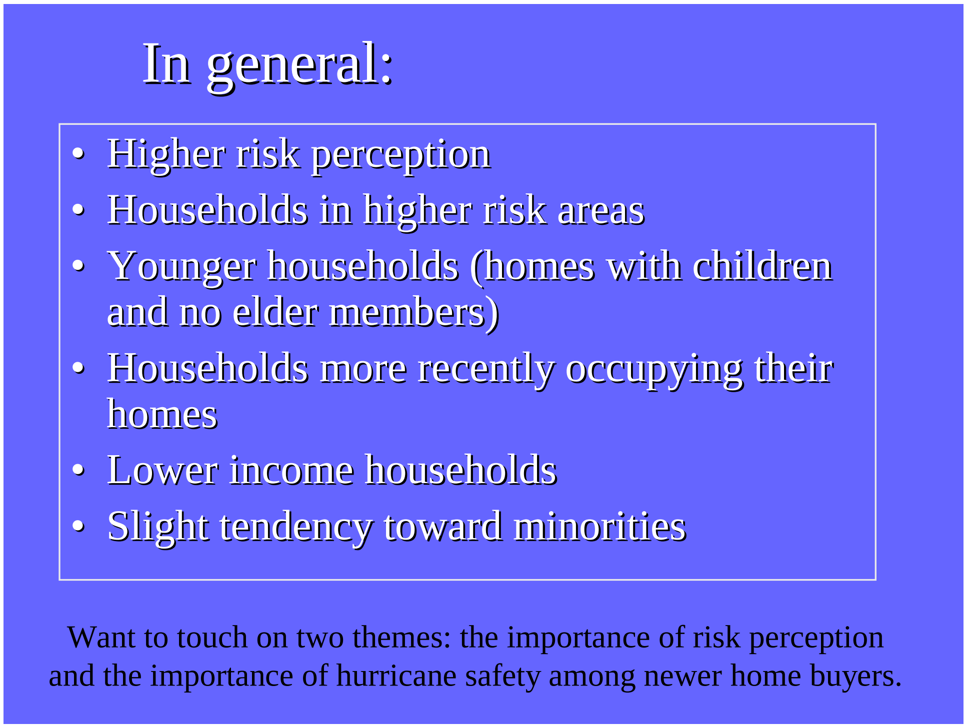
- Low-Interest Loans:
  - Those with higher hurricane risk perception
  - Lower income households
  - Younger households (with children and without elders)
  - Those with hurricane experience
  - Those in higher risk wind zones
- Forgivable Loans:
  - Younger households (non-elder households and those without elder members)
  - Households that have been in resident shorter periods of time.
  - Slight tendency for minority households.
  - Those with higher hurricane risk perception.

Slide 19.

What types of households respond to different incentives

- Lower Insurance Premiums:
  - Younger households (non-elder households and households with children)
  - Households that have been in resident shorter periods of time
  - Those in higher risk wind zones
- Lower Property Taxes:
  - Younger households (non-elder households and those without elder members)
  - Households that have been in resident shorter periods of time.
  - Those with higher hurricane risk perception.
  - Households in higher risk areas

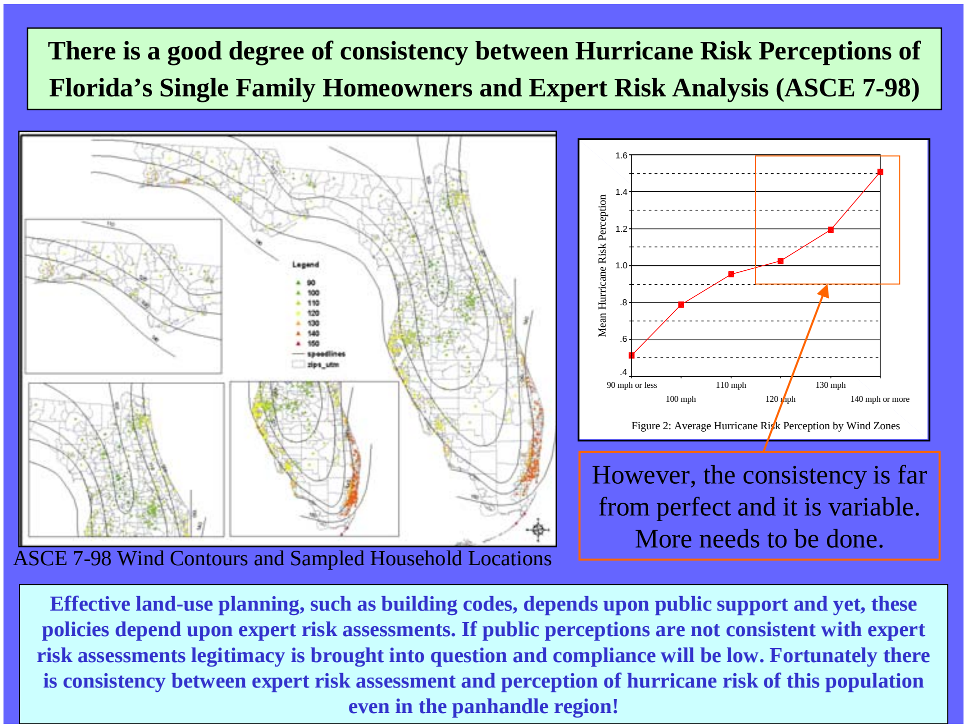
Slide 20.



In general, as suggested in Slide 20, households with higher hurricane risk perceptions, households located in higher risk areas (as assessed by wind contours), younger households, particularly those with children, households more recently occupying their homes, lower income households, and minority households are much more likely to report receptivity to various types of incentives. Hence these results point to target households that are more likely to attempt to better protect their homes, if these incentives are available. However they also point to at least two other factors that are important as well. The first is risk perception and the potential role, both positive and negative, that governmental agencies can play in its formation.

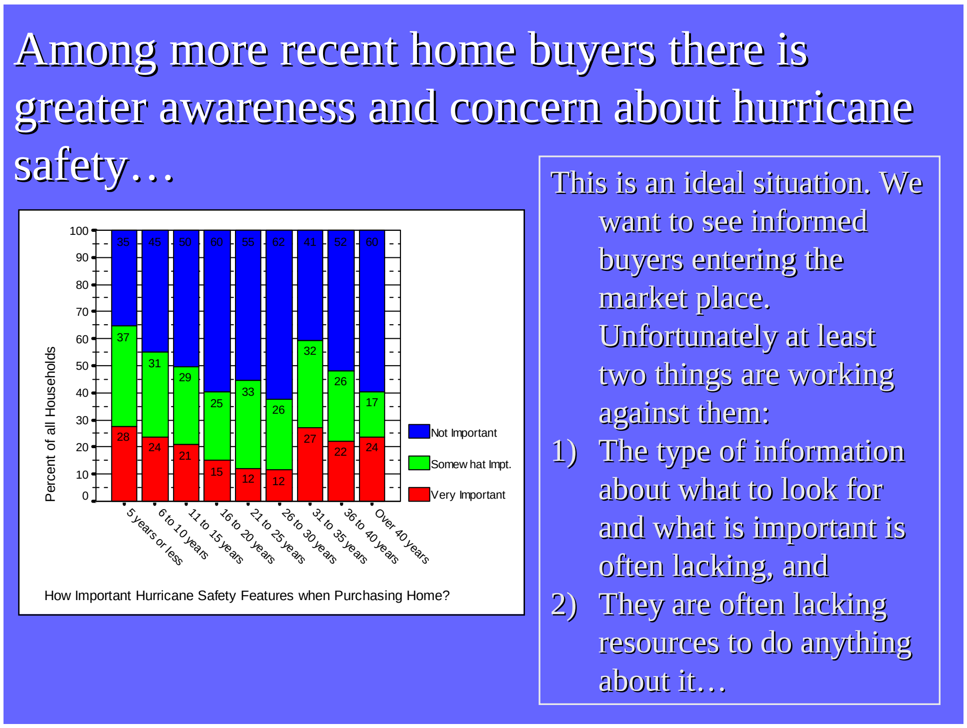
Scientific research has clearly shown that hurricane risk perception is an important factor determining whether or not households have window protection and research has also shown that there is a good deal of consistency between the wind risk zones as defined by the Florida Building Code and household perception. However that relationship is far from perfect, particularly for households in the 120-130 mph zone. As can be seen in Slide 21, residents in that zone – regardless of where they live in Florida, have risk perceptions that are much more like households in lower wind zones than those in higher wind zones (see upper right hand corner of this slide). The State and local governments should do more to educate households in this zone about the real nature of their risks to wind damage resulting from a hurricane. Indeed, the State, by exempting large areas of the Panhandle has actually introduced an inconsistent message to the residents of Florida. If this zone is dangerous, as it actually is, for those residing in the peninsula, why is not dangerous for those in the Panhandle? Disaster research has clearly shown that messages must be consistent. This inconsistency has consequences for any attempt at properly educating the population and getting people to act on that important message. The State should seek to provide a consist message regarding wind risk and further educate its population.

Slide 21.

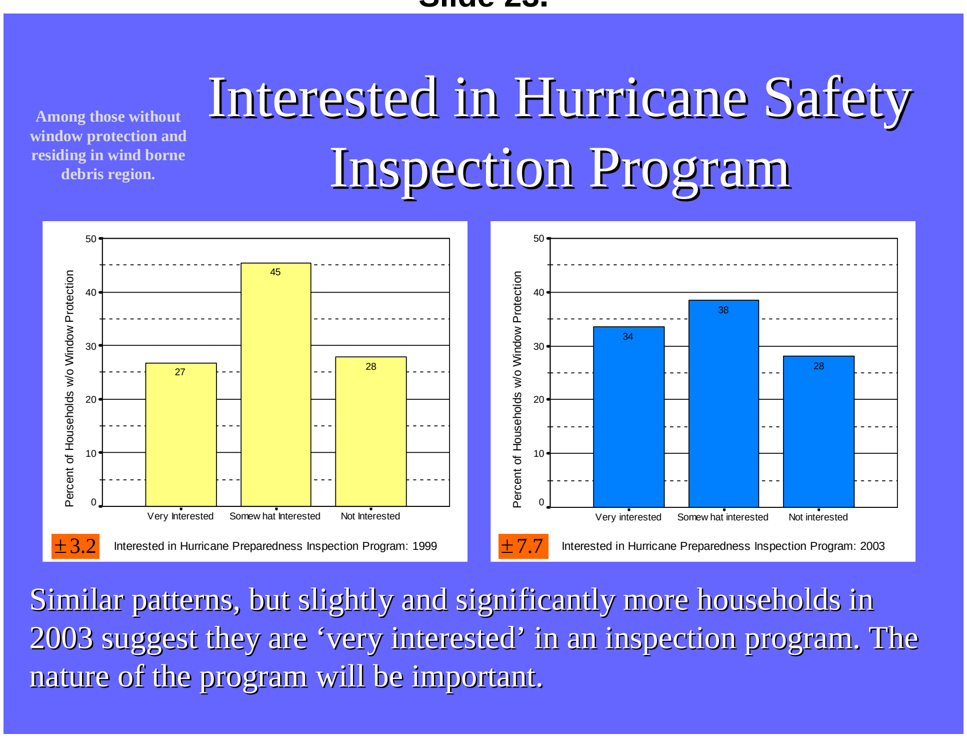


In addition, there is a real opportunity to educate households and stimulate their likelihood to improve their homes if households that are about to buy their homes are given opportunities to make improvements as they get into their homes, rather than afterward. As can be seen in Slide 22, more recent homebuyers are more likely to report that hurricane safety features were important in their decisions. Unfortunately two things are working against them making good decisions. First, many do not know what they should be looking for when examining their homes. They need education materials and home inspections should specifically note both the positive and negative hurricane mitigation features of potential homes. This will undoubtedly help potential buyers make more intelligent decisions and will stimulate market changes. In addition, programs that offer new homebuyers the opportunity to increase their mortgages in order to make code approved wind retrofits (i.e., purchasing shutters, adding tie-downs, etc.) to their home at the time of purchase should be explored. In previous research recent homeowners often mention that they would get shutters, but they have very little economic wherewithal to support such an expenditure having just purchased their home. Furthermore, research shows that consumers are often more willing to increase their costs, when they have already decided to make a major purchase. In other words, adding a few thousand dollars to make ones home more hurricane save, when you have already decided to spend over $100,000 to purchase a home, is much more likely than deciding to make the same purchase a couple of years later.

Slide 22.



Slide 23.

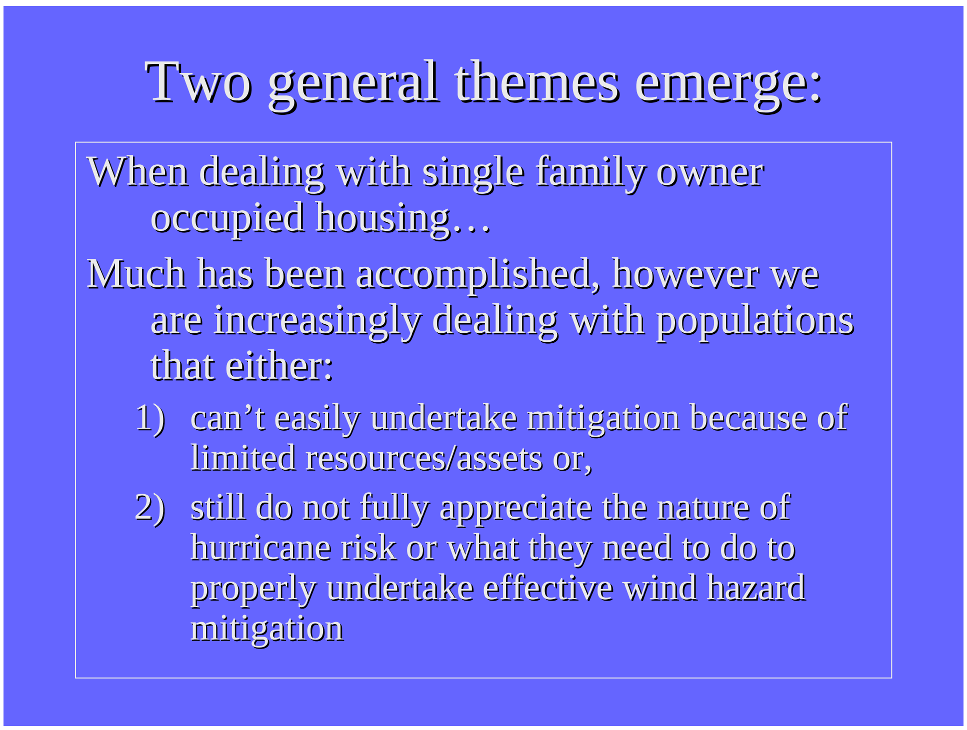


The final incentive program considered was that of a no cost hurricane safety inspection and the results presented on Slide 23 suggest that will the pattern between 1999 and 2003 are similar, on the whole more households are interested in such a program. However, other research also suggests that if the county or state operates such a program, because these are entities that are also charged with code enforcement, interest will decrease. Hence, such a program should be operated by a non-governmental organization, for profit or non-profit, rather than by the government.

Summary and Conclusions:

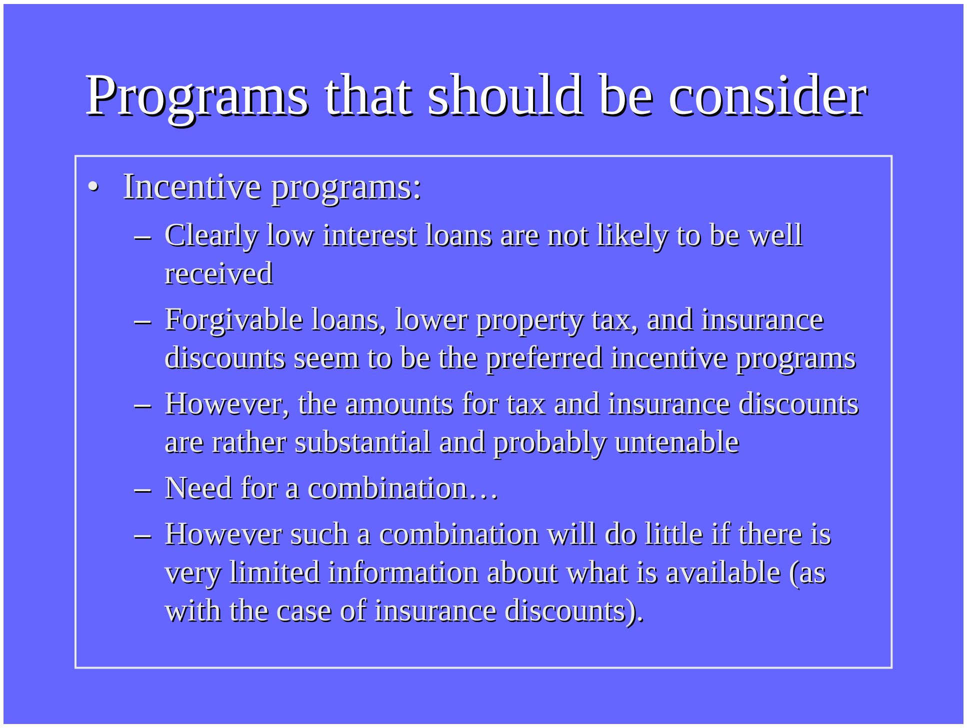
Slides 24, 25, and 26 offer brief summary and concluding statements with regard to the overall findings and suggestions.

Slide 24.

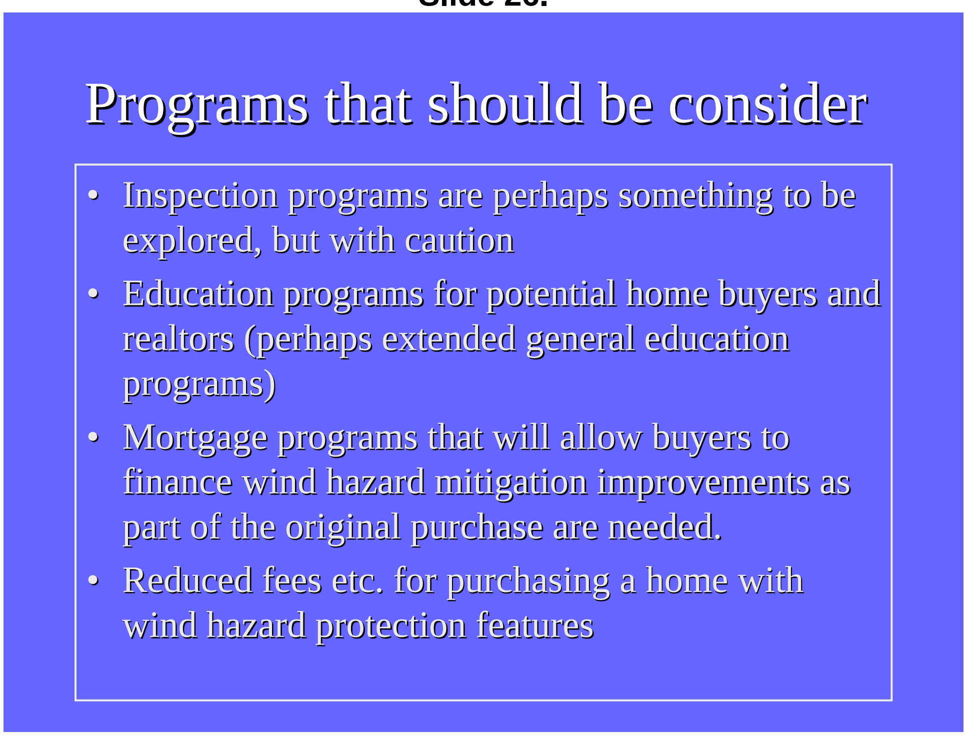


It is easy to conclude that there have been major successes, for indeed there have. The fact is that we have seen major improvements in the hurricane mitigation status of households residing in single-family owner occupied housing particularly in areas that have now come to be defined as high wind hazard zones. Unfortunately it is also the case that rather large proportions of the household that do reside in the wind-born debris zone are either without any protection or have insufficient protection. Hence, we have a long way to go. Based on the findings discussed above, Slides 25 and 26 offer some suggestions about where to place some of the priorities in terms of incentive programs.

Slide 25.



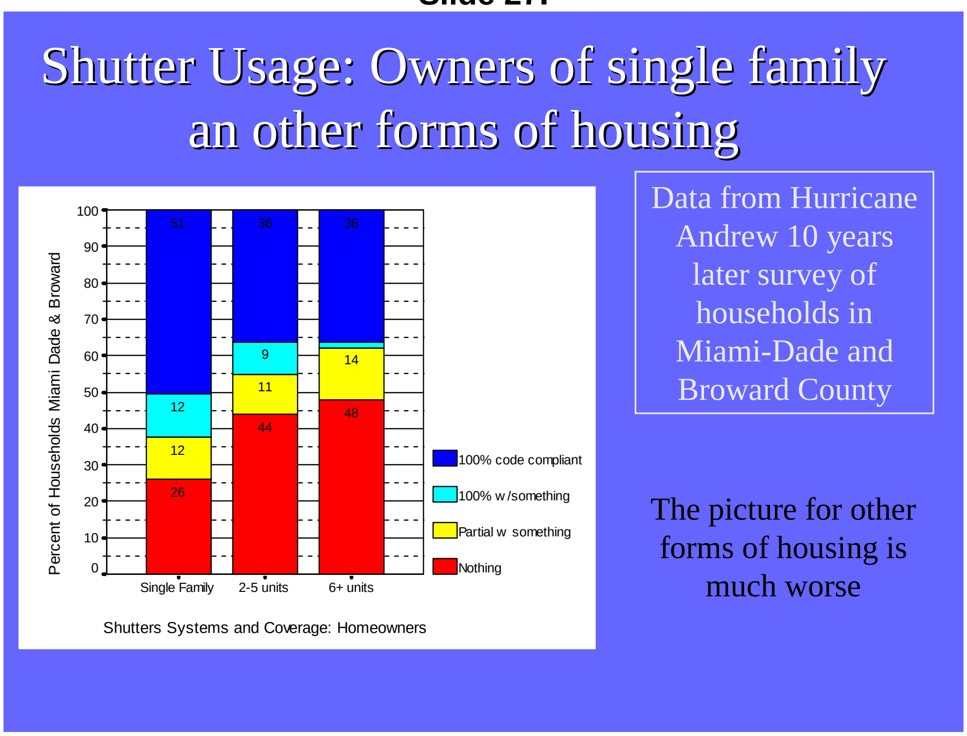
Slide 26.



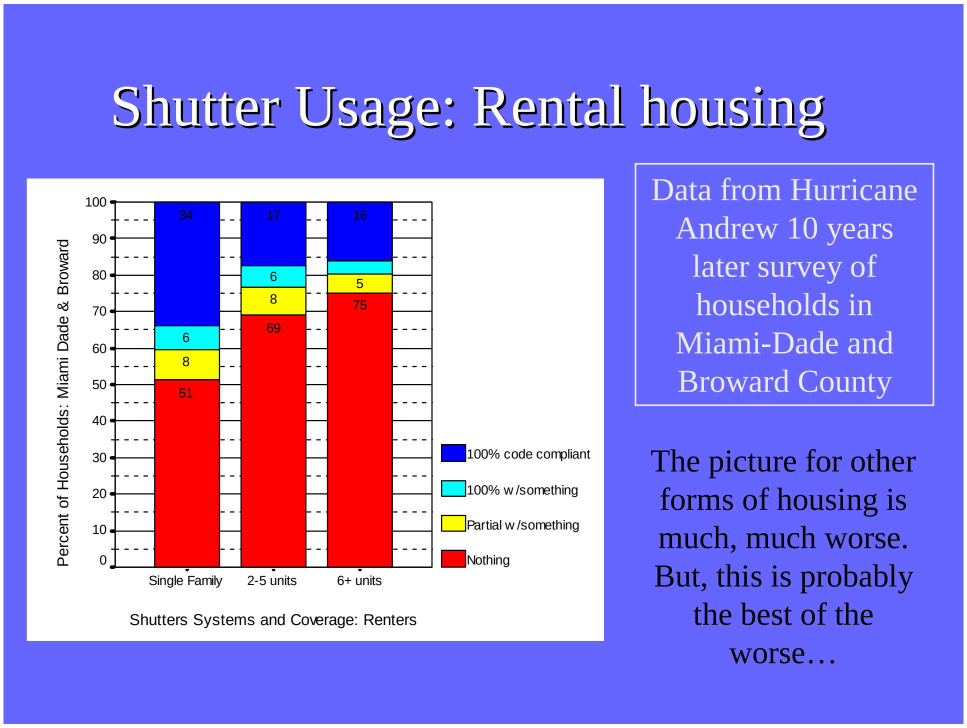
The other major issue lurking just behind these findings is that we are only looking at a portion of all housing in Florida. The fact is that in many areas we often find single-family housing is only part of the owner occupied housing and furthermore, and perhaps more importantly, much of the housing is rental housing. Indeed, in some areas around the state, rental housing is the majority of housing in the area. There is no clear data on the hurricane mitigation status of these other forms of housing.

In order to gain some idea about how these other forms of housing fair, data from a recent survey conducted in Miami-Dade and Broward counties is examined. These data were collected in the summer of 2002. When examining these data it should be kept in mind that in general housing in Miami-Dade and Broward counties, particularly since there have been major improvements in building codes since hurricane Andrew in 1992, is likely to reflect the best possible picture of the hurricane mitigation status in the state. Slide 27 presents data on window protection for various forms of owner occupied housing and Slide 28 presents similar data for rental housing.

Slide 27.



Slide 28.



As can be clearly seen in these slides, the picture is much worse for other forms of owner occupied housing, where were find much higher percentages of homes with no window protection at all. And the picture goes from bad to much, much worse for rental housing. Just over 50% of single family rental housing has no window protection at all and that percentages climbs to 75% of rental housing in multi-family structures with more than 6 units. Clearly there is much more that needs to be done to assure that all of Florida's families and households are hurricane safe.

It is equally clear that we really have very little knowledge regarding these other households and their actual mitigation status or better stated, their hurricane safety status throughout the state. Furthermore, the factors that influence hurricane safety and related decisions among these other households are likely to be very different than those among homeowners. It is our hope to develop a better picture and understanding of these issues in the near future, should we be able to obtain funding to conduct research among these types of households and the landlords or rental companies that make decisions about these types of homes.

Appendix D
Sample Invitation

Jim Rivers, Ph.D.
Director, Laboratory for Social and Behavioral Research
International Hurricane Research Center
University Park Campus, FIU
MARC 362
Miami, FL 33199

(Date)

To: Those who wish to contribute to a discussion of mitigation incentives

We hope that you are a person who will be interested in Florida International University's Mitigation Incentives Workshop to be held on April 1, 2004. The purpose of this workshop is to use statewide homeowner survey research findings and the results from the recommendations made by the Homeowner's Incentive Team in 1999 to inform policy and programs that will help owners of residential properties better mitigate their structures. (a separate agenda and information on the Homeowner's Incentive Team recommendations are attached)

Your organization is encouraged to send a representative who can contribute to a discussion of what you would like to see in the way of incentives for owners of residential property to take mitigation actions. Invitees include, but are not limited to, representatives from **banking, the building industry, utilities, government, insurance and real estate** sectors. The workshop welcomes representatives from organizations that manage commercial residential properties and those who represent condominium groups, as well.

There are no workshop attendance fees, and parking passes are available for those who RSVP their attendance. A continental buffet breakfast and an executive buffet lunch will be provided.

Participation by organizations such as yours is crucial to the success of this workshop. **Please be advised that the location of the workshop is the College of Engineering building (CEAS) 10555 W. Flagler St. Miami, FL 33174 in room 2300.**

Use the west entrance on 107th Avenue, just north of SW 8th Street and get your parking permit from us in the lobby before proceeding to the meeting room.

If you have any questions, please call (305) 348-1146 (Anthony Peguero, Deirdra Hazeley, or Amy Reid) or me (Dr. Jim Rivers) at (305) 348-1228. RSVP at these numbers or by e-mailing riversj@fiu.edu with your organization's name and who the representative/participant will be.

We hope to see you or someone from your organization at the workshop on April 1, 2004.

Sincerely,

James E. Rivers, Ph.D.

Appendix E

IHRC Laboratory for Social and Behavioral Research
Hurricane Mitigation Incentives Workshop

Thursday April 1, 2004

Agenda

8:30 Continental breakfast buffet

9:00 Welcome: **Ricardo Alvarez, Laboratory for Structural Mitigation**
Jim Rivers, Laboratory for Social and Behavioral Research

9:15 Opening remarks and Update: 1999 Homeowners Incentive Team project
Charles McCool, Florida Department of Community Affairs

9:45 Analysis and summary of findings from previous statewide surveys of mitigation incentives and programs
Walter Peacock, Texas A& M University
- Whose homes are protected?
- Why aren't some homes protected?
- What might it take to stimulate protection?

10:45 Break

11:00 Discussion of HIT recommendations, post-HIT incentives, and results of homeowner surveys

12:00 ***** Executive Buffet lunch and re-assemble in small groups*****

Small Group Task: Discussion of prospective new or enlarged initiatives (with facilitators and note takers)
Self-selected (at check-in) small groups:
- Insurance
- Financing – construction, retrofitting
- Tax rebates
- Condominium Associations
- Commercial Residential Property Owners

1:30 Break

1:45 Plenary: Reconvene to report small groups' recommendations

3:00 Adjourn

Funded by Florida Department of Community Affairs

Appendix F

Organizations Invited

Federal National Mortgage Association (Fannie Mae)
Florida Association of Mortgage Brokers
Florida Bankers Association
Florida Housing Finance Corporation
Mortgage Bankers Association
Building Industry Association of South Florida
Florida Building Materials Association
Florida Home Builders Association
Institute for Business and Home Safety
Florida Electric Power Coordinating Group
Florida Municipal Electric Association
Flood Emergency Management Agency
Florida Association of Counties
Florida Department of Community Affairs
Florida Department of Insurance
Florida League of Cities
U.S. Department of Housing and Urban Development
Allstate Insurance
Florida Association of AIA
Florida Farm Bureau
Florida Insurance Council, Allstate Insurance
Mid-Atlantic Risk Management, USAA
Nationwide Mutual Insurance
State Farm Insurance
United Services Automobile Association
Association of Realtors
Broward County Property Appraiser Department
Florida Association of Property Appraisers
Applied Research Associates
International Hurricane Research Center

Appendix G

List of Participants

Ricardo Alvarez	International Hurricane Research Center, FIU
Alexander Castellanos	Advance Capital Services, Inc.
Hugh Gladwin	Institute for Public Opinion Research, FIU
Herminio Gonzalez	Building Code Compliance Office Florida Association of Counties
Shahid Hamid	International Hurricane Research Center**,** FIU
Rick Herrera	Housing, Planning and Development Miami-Dade Housing Agency
Juanita A. Mainster	International Hurricane Research Center**,** FIU
Steve Mainster	Centro Campesino Farmworker Center, Inc.
Charles McCool	Residential Construction Mitigation Program Florida Department of Community Affairs
Erin Mohres	Miami-Dade Office of Emergency Management
Walt Peacock	Department of Landscape Architecture and Urban Planning, College of Architecture, Texas A&M University
Frank J. Reddish	Miami-Dade Office of Emergency Management
Carolyn Robertson	International Hurricane Research Center, FIU
Harvey G. Ryland	Institute for Business and Home Safety
Dilip Surana	City of Miami
Bashir A. Wayne	Recovery & Hazard Mitigation Department of Fire –Rescue/City of Miami

Appendix H

STEERING COMMITTEE
Laboratory for Social Science Research
Florida International University

Dr. James Rivers, Director

Dr. Stefanie A. Klein, Research Scientist

Ms. Deirdra H. Hazeley, Graduate Research Assistant

Mr. Anthony Peguero, Graduate Research Assistant

Ms. Amy Reid, Graduate Research Assistant

3.8 PROGRAMS OF EDUCATION AND OUTREACH TO CONVEY THE BENEFITS OF HURRICANE LOSS MITIGATION DEVICES AND TECHNIQUES

In the past the IHRC team has conducted and developed various techniques that offer hurricane loss reduction techniques to the private and public sectors. The findings and recommendations of this research are published in a final report submitted to the Department of Community Affairs and various scientific journals. Often this pertinent and valuable information is slow to make its way to the public's ears. This year an effort was placed not only on conducting state-of-the-art research, but also making sure that the findings and recommendations reached the public. The IHRC team holds the view that the objectives of the HLMP, especially the promotion of hurricane loss mitigation devices and techniques, will be achieved to the degree that a culture of mitigation is created among the residents of vulnerable communities everywhere as well as stakeholders from all sectors of society.

The education and outreach components initiated this year built on the foundation of research and work predominately conducted during the 2002/2003-grant period. The research team participated in several venues where the work of the IHRC under the Hurricane Loss Mitigation Program (HLMP) could be showcased and shared with others as a way of promoting hurricane-loss mitigation and the objectives of the HLMP. Efforts this year were placed to increase the level of awareness among the general public regarding the need for decreasing the vulnerability of building structures to hurricane force winds. Efforts were also made to build partnerships with local and statewide organizations to coordinate interrelated activities and ensure cooperation among parties implementing hurricane loss reduction activities. In addition the team continues to maintain a web page for the Laboratory for Structural Mitigation under the URL: *www.mitigation.fiu.edu.*

Outreach initiatives were achieved through several platforms including conferences, organized presentations, temporary exhibits and scientific displays and interaction with the homebuilders industry via survey. The following is an account of those activities

Conferences

Outreach was conducted at four statewide conferences to ensure that the businesses, organizations, and agencies were aware of on-going research activities conducted through the HLMP program and the applications of this research to personal mitigation strategies. The conferences included: the Southeast Builders Conference August 2003, the South Florida Hurricane Conference June 2004, the Governor's Hurricane Conference May 2004, and the National Hurricane Conference April 2004. Participation in these programs was by way of chairing workshops and delivering presentations focusing on hurricane loss mitigation. An exhibit booth complemented these presentations where IHRC staff was present to answer questions or to distribute information about research initiatives related to the topic of hurricane loss mitigation (Figure 1).

Meetings and Special Presentations

Researchers from the IHRC had continuous interaction and participation in the activities of the Miami-Dade County Local Mitigation Strategy Working Group. IHRC team representatives made several presentations throughout the year on issues related to hurricane loss mitigation in general and to the HLMP in particular. In December 2003 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 during 2003 in Miami-Dade County.

In addition, the IHRC hosted various groups, media representatives and schools, at the Laboratory for Structural Mitigation to demonstrate various tests being conducted under the HLMP as a way of sharing knowledge and findings from such research in order to foster the objectives of the HLMP.

Educational Displays

Hurricane Warning Project

"Hurricane Warning! Project" is a planned learning center where citizens can experience and understand the affects of a hurricane event. The learning center, still in the process of being developed, will be located in a 50,000-square-foot building in Deerfield Beach, Florida. Presently the Hurricane Warning Project is located in the former State Farm Safe House. During the development stage, the IHRC has donated a tabletop wind tunnel and several educational posters. This information will be utilized to teach visitors the importance of decreasing the vulnerability of homes to hurricane force winds.

Hurricane Awareness Exhibit

Funds were allocated to create a "Hurricane Awareness Week" exhibit located at the Miami Children's Museum, during a weekend in May 2004. The IHRC created a partnership with the museum to create interactive displays that portrayed the importance of hurricane awareness, preparedness, and mitigation techniques. Interactive games included a giant jigsaw puzzle displaying a hurricane, a "packing station" which enabled children to make decisions regarding the types of items they should take to a hurricane shelter in case an evacuation was enacted, and a "clean-up" game that taught children actions that must take place during a hurricane recovery effort. In addition to these games a tabletop wind tunnel was used to demonstrate the effects wind loads have on different architectural features of a home.

Several models of typical South Florida homes were placed inside the test chamber of the wind tunnel. Volunteers from the audience were allowed to use a remote control to start the wind generator. Visitors of the exhibit could then witness first hand how building shapes, architectural features and wind direction affect the relationship between the structure and the wind field.

At the completion of the four activities children received a take home activity packet and certificate of participation. The activity packet was intended to promote conversation about hurricane awareness and preparedness with the child and family members at home. Activities consisted of word searches, coloring pages and a children's story about hurricanes (compliments of FEMA).

In addition to the interactive display, participants from the K-12 Project were asked to display their science projects in the promenade of the museum. The International Hurricane Research Center has sponsored the K-12 Program since 2001, the purpose of which is to develop a culture of mitigation through education. Currently 7 schools participate in the program. The display section of the exhibit allowed forty elementary level children from the St. Lawrence School and Miami Christian School to display and present their mitigation projects to museum visitors. This "children teaching children" portion of the exhibit encouraged museum visitors to engage in conversations with the K-12 children in regards to their various types of loss reduction projects that ranged from topics of terrorism to natural disasters.

It was estimated that 500 children participated in the two-day exhibit. In addition to the excitement of the children, adults were quick to praise the IHRC's efforts in relaying this important information about hurricane awareness and hurricane loss reduction strategies for homes. In many cases parents were surprised at the level of gained "hurricane knowledge" their children experienced from participating in the exhibits.

Figure 1. Governor's Hurricane Conference

Figure 2. Children examining the table top wind tunnel at the Miami-Dade Children's Museum

Figure 3. Example of Mitigation Poster

Figure 4. K-12 participants displaying project at the Miami Children's Museum

Interaction with Homebuilding Industry

The IHRC promoted an interaction with the homebuilding industry in an effort to identify ways to encourage homebuilders to offer and promote effective hurricane loss mitigation measures to prospective home-buyers together with a full menu of options offered to them.

The initial thrust of this activity involved a survey of homebuilders throughout Florida conducted over the Internet. The survey instrument consisted of seven [7] questions that could be answered by way of a few mouse clicks and then returned over the Internet to the IHRC web page, where results were tabulated.

The survey questionnaire was sent to approximately 6,500 homebuilders throughout Florida. Approximately 2,400 messages were returned for a combination of reasons including errors in the address database, or systems blocking reception as a precaution against what may have been identified as “spam” because the originating address had not been registered at the recipient’s system.

Of the remaining 4,100 recipients only 68 fully completed questionnaires were returned or about 1.5% return ratio. While this was quite a low rate of response, it nevertheless provided useful information.

The seven questions included in the survey and the answers received were:

Question 1: ***Did you know that many first time homebuyers consider hurricane mitigation a vitally important issue, one that could help them secure their investment, in making a decision to purchase a new home?***

YES = 49 **NO = 19**

Question 2: ***Would you consider offering additional mitigation alternatives, beyond the requirements of the building code, if this could give you a marketing advantage in promoting your housing project?***

YES = 55 **NO = 13**

Question 3: ***Would you be wilin to offer some of these more expensive protective devices [****referring to shutters and other impact* *protection measures]* ***together with other options you would normally offer prospective homebuyers?***

YES = 58 **NO = 10**

Question 4: ***If the answer to the previous question is YES, do you think this will give you a marketing advantage in promoting your housing project?***

YES = 50 **NO = 18**

Question 5: ***Do you as a homebuilder provide alternative mitigation measures other than those required by the Florida Building Code?***

YES = 46 **NO = 22**

Question 6: ***In what county or counties do you build houses? Please identify. [***the survey provided a drop menu with a list of all Florida counties and allowed the responder to select up to three different counties]

Question 7: ***As an average, how many houses do you build annually?***

___	10-50	**47**
___	51-100	_
___	101-200	**2**
___	201-500	_
___	More than 500	**19**