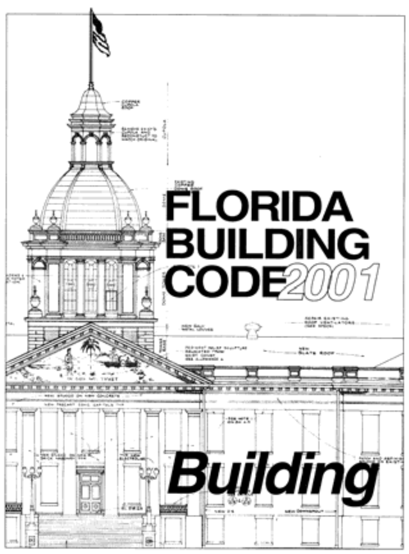
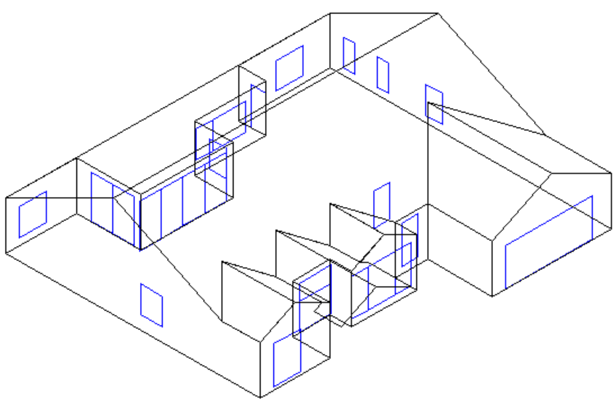
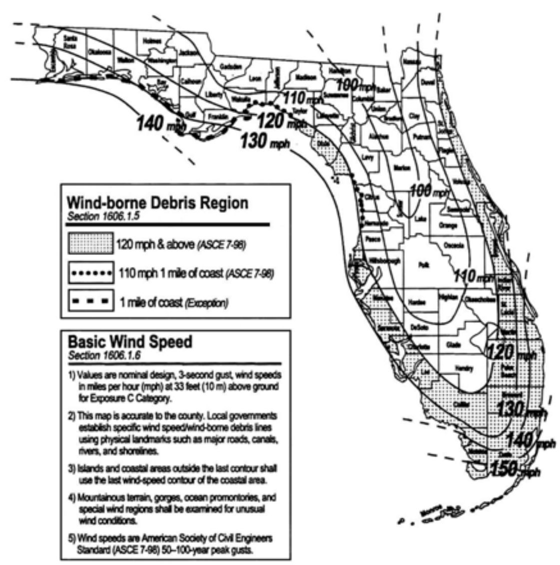
Version 2.2
March 28, 2002

Florida Department of Community Affairs

Development of Loss Relativities for Wind Resistive Features of Residential Structures







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PREFACE

(Version 2.2)

The Florida Department of Community Affairs contracted with Applied Research Associates, Inc. to evaluate the effectiveness of wind resistance features in reducing hurricane damage and loss to single family residences in Florida. The project was begun in September 2001 and completed in March 2002. The scope of the project has dealt with both existing construction and new construction built to the new Florida Building Code 2001. The Florida Building Code (FBC) became effective on March 1, 2002.

The scope of this study was limited to single family residences. A companion project is underway to address multifamily residential occupancies and produce a similar set of guidelines by July 2002.

The DCA, DOI, and ARA make no representations on the possible interpretations in the use of this document by any insurance company. The use of information in this document is left solely to the discretion of each insurance company.

The draft version (Version 2.1) of this report was made available for public comment in February and March 2002. Version 2.2 includes updates to the deductible analysis (Section 3.5), simplification to the foundation restraint modification (Section 3.3.6), a new section on statistical error (Section 3.6), minor simplifications to Table 4-2, and a new discussion on limitations and suggestions for further work (Section 6.6). Minor edits have also been made and typos corrected throughout.

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These comments may be considered in possible future updates to this study.

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EXECUTIVE SUMMARY

A project has been conducted to estimate the effects of wind-resistive building features in reducing hurricane damage and loss to single family residential structures located in the state of Florida. The scope of this project has included both new construction to the Florida Building Code 2001 and existing construction. An analysis of the building stock distribution for existing construction has been developed to aid users in the computation of average rating factors.

The basic approach used in this study to develop the loss relativities has involved the analyses of individually modeled buildings at numerous locations in Florida. Each building has been modeled with a specific set of wind resistive features. The features considered in this project include: roof shape, roof covering, secondary water resistance, roof-to-wall connection, roof deck material/attachment, opening protection, gable end bracing, wall construction, and wall-to-foundation restraint. For new construction, the buildings have been designed to the FBC 2001 according to the design wind speed, wind-borne debris region design options, and FBC definitions of Terrain Category. In the wind-borne debris region, designs for both enclosed and partially enclosed structures have been evaluated, per the FBC and ASCE 7-98.

The loss cost relativities for existing construction are developed in the form of a set of tables. Two main tables are provided for the seven primary rating factors, one set for Terrain B and one set for Terrain C. Additional tables are used for four secondary rating variables. These tables are normalized to a "central" house, which is a representative house as opposed to the weakest house. The relativity for the central house is one and the relativity for a very weak house is 2.37 for Terrain B and 1.60 for Terrain C. A very strong house has a relativity of 0.41 for Terrain B and 0.21 for Terrain C. These relativities are all computed for 2% deductible. The Terrain B results are primarily for inland locations and the Terrain C results are primarily for barrier islands and locations within 1500 feet of the coastline.

For new construction to the Florida Building Code (FBC), the loss relativities have been computed and reduced to a single table for minimal design loads. The loss relativities for minimal design construction to the FBC range from 0.5 to 0.76 in Terrain Exposure B for the case of no opening protection. When the openings are protected for wind borne debris impact, the loss relativities reduce to 0.41 to 0.48. In Terrain C, the loss relativities range from 0.3 to 0.38 for no opening protection and 0.23 to 0.27 for openings protected for impact resistance. In Broward and Miami-Dade Counties, opening protection is required for all new construction and the loss costs relativities range from 0.23 to 0.26. Since new construction may be designed for higher loads that the FBC 2001 minimums, a separate table of adjustments is provided for these cases. In addition, this table can also be used for new homes that are later mitigated beyond the code minimums.

The analysis results for new construction clearly indicate that the Florida Building Code 2001 will improve the design and construction of new buildings in the state. The loss relativities for new construction are much less than the average rating factors for existing construction.

The building stock distribution analysis for existing residences in Florida has been developed primarily from the Residential Construction Mitigation Program database of inspected homes. Four regions and three construction eras were identified to provide an approximate method for estimating the distribution of business. Each user can compute its distribution of business by year built in each region. The average rating factors by region and era can then be used to develop portfolio-specific average rating factors.

Further improvement and refinement of the work performed in this project may lead to improved estimates of relativities in the future. The report discusses areas where more data is needed as well as house features that have not been explicitly modeled.

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1.0 INTRODUCTION

1.1 Objective

Florida Statute 627.0629 reads, in part, as follows:

> *A rate filing for residential property insurance must include actuarially reasonable discounts, credits, or other rate differentials, or appropriate reductions in deductibles, for properties on which fixtures or construction techniques demonstrated to reduce the amount of loss in a windstorm have been installed or implemented. The fixtures or construction techniques shall include, but not be limited to, fixtures or construction techniques which enhance roof strength, roof covering performance, roof-to-wall strength, wall-to-floor-to-foundation strength, opening protection and window, door, and skylight strength. Credits, discounts, or other rate differentials for fixtures and construction techniques which meet the minimum requirements of the Florida Building Code must be included in the rate filing. …*

The purpose of this study is to produce a public domain document that provides data and information on the estimated reduction in loss for wind resistive building features for residential property insurance.

1.2 Scope

The scope of this study must include, as a minimum, the wind resistive features called out in the statute, namely:

1. Enhanced Roof Strength
   a. Roof deck connection to roof framing
   b. Roof deck material and strength
2. Roof Covering Performance
3. Roof-to-Wall Strength
4. Wall-to-Floor-to-Foundation Strength
   a. Wall-to-floor strength
   b. Floor-to-foundation strength
5. Opening Protection
   a. Windows
   b. Doors
   c. Skylights

In addition, the study addresses some other features that have been demonstrated to reduce the amount of loss in windstorms.

The scope is limited to single-family residential buildings. Commercial-residential or commercial occupancies are not considered.

This project uses hurricanes as the windstorm to produce the loss relativities. Hurricanes dominate the severe wind climate in Florida and, hence, are the primary contributors to windstorm loss costs.

The scope of this project includes both new and existing construction. There are existing homes in Florida that have construction techniques and fixtures that reduce the losses in a windstorm. Many of these existing features are similar to, or may even exceed, the requirements of the Florida Building Code (Florida Building Code 2001). Hence, existing homeowners should also have the opportunity to qualify for rate differentials, similar to new construction.

The features for which discounts are provided must be practically verifiable so insurers can be reasonably confident a particular house qualifies for the discounts.

The scope of work also includes an analysis of the building stock distribution for existing construction. This information is provided to aid insurers in the calculation of average rating factors.

1.3 Technical Approach and Limitations

The basic approach used herein to estimate how loss costs change with wind resistive fixtures and construction techniques relies primarily on engineering models and loss analysis for individual buildings. The buildings are modeled with and without specific wind resistive fixtures. These buildings are then analyzed for hurricane damage and loss using Applied Research Associates, Inc.'s, HURLOSS methodology. The HURLOSS methodology has been reviewed and accepted by the Florida Commission on Hurricane Loss Projection Methodology. The public domain documents on HURLOSS are available from the Commission. In addition, this report provides further information on the model and its validation. Technical papers are also referenced.

An advantage of the individual building modeling approach used for this study is that it is based on a detailed engineering model that replicates how engineers design and analyze real structures. A similar approach has been adopted by the Federal Emergency Management Agency (FEMA) in the development of a National Wind Loss Estimation Methodology. The engineering load and resistance modeling methodology used in this approach has been reviewed by the Wind Committee of the National Institute for Building Science. This committee includes national experts in wind engineering and meteorology.

The estimation of losses for buildings with specific engineering details is an emerging technology and has many limitations. The treatment of uncertainties and randomness in the hurricane wind field, wind boundary layer, the built environment, building loads, resistances, and loss adjustment are an important part of the modeling process. The data sources include: historical data, wind tunnel test information, building code information, post-hurricane damage surveys, laboratory tests, full-scale tests, insurance claim folders, and insurance company portfolio exposure and loss data.

Judgments are used to supplement this modeling process. The HURLOSS computed relativities have been compressed using a judgment factor. The resulting loss relativities, while reasonable estimates at this time, are likely to evolve with more data and further model improvements.

A final comment is that the scope of this project was extremely complex and the schedule limited. Major pieces of the work were done in parallel and many simplifications were needed to produce a final product. There is clearly room for refinement and improvement and a strong need for more data.

1.4 Florida Building Code

The State of Florida first mandated statewide building codes during the 1970s, requiring local jurisdictions to adopt one of the model codes. The damage produced by Hurricane Andrew and other disasters in the 1990s revealed fundamental building code weaknesses and also that building code adoption and enforcement was inconsistent throughout the state. The state has attempted to respond to this situation by reforming the state building construction system with emphasis on uniformity and accountability. The Florida Building Code (FBC) is the central piece of the new building code system. The single statewide code is developed and maintained by the Florida Building Commission.

The FBC supersedes all local codes and is automatically effective on the date established by state law. The new building code system requires building code education requirements for all licensees and uniform procedures and quality control in a product approval system.

The FBC is compiled in four volumes: Building, Plumbing, Mechanical, and Fuel Gas. The National Electrical Code© is adopted by reference. This scope of this project has been limited to wind resistive construction features, which are in the Building Volume.

Section 4 and Appendix E provide additional discussion on specific requirements of the FBC with respect to wind mitigation features.

1.5 State-of-the-Art in the Classification of Buildings for Wind

The commonly used insurance construction classes are based on the ISO classes, which were originally developed primarily for fire risk classification. The ratings with respect to masonry, semi-wind resistive and superior frame, while capturing some of the differences in the performance of the main structural system with respect to wind loads, do not address the key causes of wind damage and loss associated with roof covering, window and door performance, roof deck, roof-to-wall performance, and building aerodynamics. These ISO classes are still commonly used by the insurance industry, but it is widely recognized that these classes are not ideal for wind ratings.

Several developments have taken place in the past few years that focus on an emerging fundamental change in the classification of buildings for wind damage and loss.

First, FEMA has begun the development of a national wind loss estimation methodology. This methodology includes the development of a detailed classification system for buildings based on the wind damage and loss characteristics. While this work is not publicly available at this time, the initial version will be published in late 2002 to early 2003.

Second, the Residential Construction Mitigation Program (RCMP) initiated by the state of Florida in 1997, has provided unique information on single-family building construction features, mitigation options and costs for existing buildings, and the expected mitigation loss reduction benefits. Detailed inspections were performed for over 2,000 houses in selected coastal counties in Florida between 1998-2000. The resulting data provides a unique source of information to help characterize the current building stock in the state.

Third, the Florida Windstorm Underwriting Association (FWUA) recognized the need for wind-based insurance classes and in 1998-1999 developed a first generation Class Plan aimed at classifying buildings by their wind risk characteristics rather than the ISO fire based characteristics. The FWUA Class Plan has been in effect since July 2000 and residential occupancies (single-family and 1-4 unit occupancy/buildings) are being rated according to the construction features in their Class Plan. The loss relativities in their Class Plan were based on actuarial judgment coupled with model calculations of the type used in this study.

Examples of the characteristics included in the FWUA Class Plan include roof shape (hip versus gable), roof sheathing attachment (standard vs. superior), garage vs. no garage, opening protection, porches, etc. The FWUA Class Plan has significant credits for opening protection, roof deck attachment, secondary water resistance, and roof shape. The rating factors in the FWUA plan are synergistic amongst multiple features and not simply additive. This is because each element of the building envelope is vulnerable and, hence, combinations of mitigation items interact nonlinearly.

The classification produced in this project provides a next step in the rating of residential construction. This study has involved more categories for key rating factors in construction than considered in the FWUA plan. Most importantly, this project addresses the wind mitigation requirements of the FBC. In general, however, many of the rating variables for existing construction are similar to the FWUA plan.

1.6 Review of Building Features that Influence Hurricane Damage and Loss

For many years, engineers have focused on the structural frame and load-path issues in designing buildings for wind loads. However, beginning in the 1970's, engineers began to document the importance of the building envelope (roof deck and covering, roof-to-wall connection, windows, doors, etc.) performance in influencing the resulting financial loss experienced by buildings in windstorms. In many storms, the building frame performed adequately, but the windows and/or doors failed, often due to impact by wind-borne debris. Roof covering was almost always damaged, resulting in water penetration into the building, particularly for hurricanes.

Damage and the ensuing losses to residential buildings were found to be governed by the performance of the building envelope, including many non-engineered components, such as roof covering, windows and doors, roof sheathing, garage doors, etc. The key structural frame connection for most failures was the roof-to-wall connection. Foundation failures and frame failures, other than the roof-to-wall frame connection, were found to be extremely rare for site-built houses, except in intense tornadoes. In most cases, if damage to the frame or foundation did occur, it was preceded by the failure of other components.

These observations stand in sharp contrast to earthquake induced damage to buildings, which is governed primarily by the building foundation and building frame performance.

Figure 1-1 illustrates the key building envelope features for site-built houses that affect hurricane damage and loss. For wind damage and loss, we start with the roof and work down.

Roof Covering. Roof covering performance (Fig. 1-2) is important since partial loss of the covering allows hurricane rain water to enter the building. Hurricanes are tropical storms and rain is always an integral part of the storm. Once water enters the building, the losses begin to increase dramatically. Drywall, electrical, floor coverings, and contents are easily damaged and the losses mount up quickly. Review of insurance claim folders supports these observations.

Another major problem with roof coverings is the fact that failure of the covering produces debris that is accelerated by the wind and becomes airborne "missiles" capable of easily damaging unprotected glazing. Figure 1-3 shows the typical case of roof covering failure from a house that produced impacts and multiple penetrations of the neighboring house.

Roof Deck. Roof deck attachment during a hurricane is critical to the survival of the building (Fig. 1-4). Once a building looses one or more pieces of roof deck, the losses increase exponentially due to the vast amount of water that enters the building. Field observations and insurance claim folders indicate that the house quickly becomes a major loss once the roof deck begins to fail in a hurricane. In other words, even if the walls are intact and the roof trusses do not fail, loss of roof deck and a few windows typically leads to losses greater than 50% of the insured value.

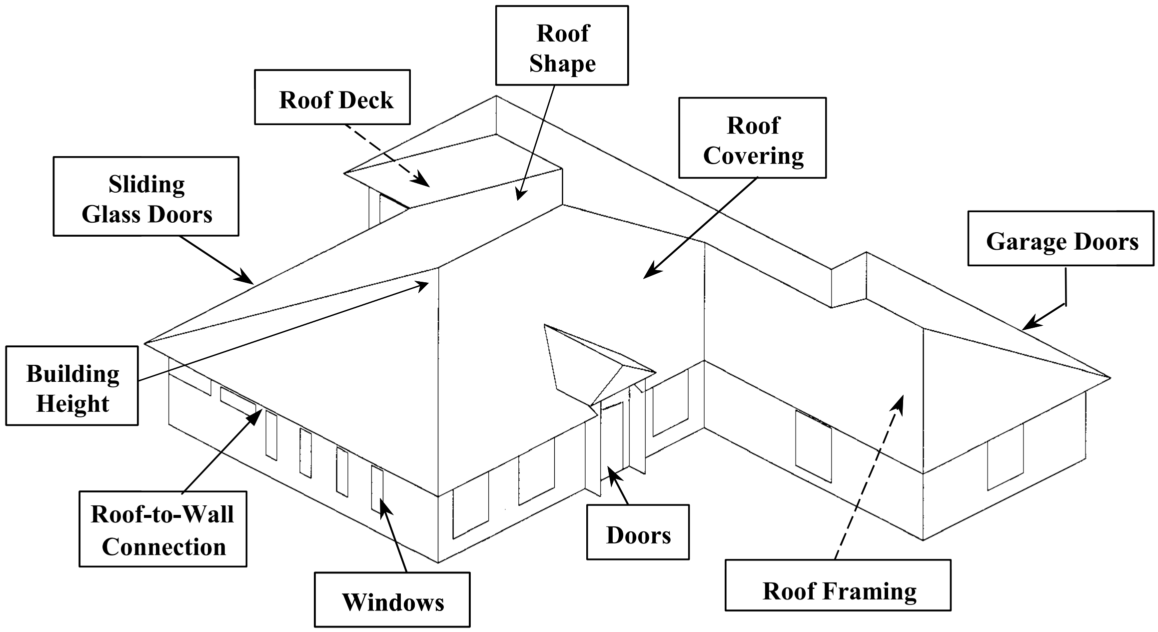


Figure 1-1. Building Envelope Features that Control Damage and Loss

Figure 1-2. Loss of Roof Covering Leads to Interior Water Damage

Roof-to-Wall Connection. One of the most important connections in a house is the roof-to-wall connection. The critical loads on the roof are negative (suction) pressures that produce uplift forces on the roof. Toe-nailed roof-to-wall connections, a relatively common building practice in the past, are especially vulnerable to failure (Fig. 1-5). Properly installed hurricane straps that connect the roof truss to the wall frame generally provide for adequate resistance to uplift roof failures. Houses with gable ends are also vulnerable to gable end wall failures (Fig. 1-6), although these failures are not, on average, large contributors to loss.

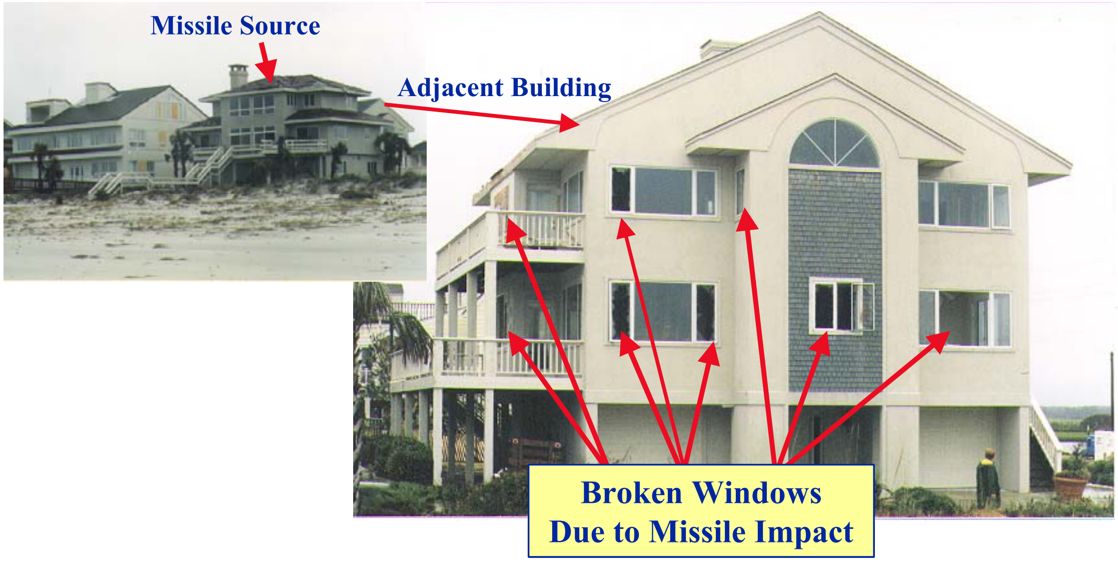


Figure 1-3. Loss of Roof Covering Produces Wind-Borne Debris

Figure 1-4. Roof Deck Performance

Roof Shape. The shape of the roof influences the aerodynamic loads experienced by the roof covering, roof deck, roof framing and connections. Figure 1-7 illustrates gable and hip houses at Navarre Beach (on the same street), following Hurricane Erin in 1995. Gables, on average, do not perform as well as hips due to roof shape aerodynamics and the lack of roof-to-wall connections on all 4 sides of the house.

Openings. Openings include windows, doors, skylights, garage doors, etc. As illustrated in Fig. 1-8, openings can fail in various ways. The most common is from impact by wind-borne debris. Once the building

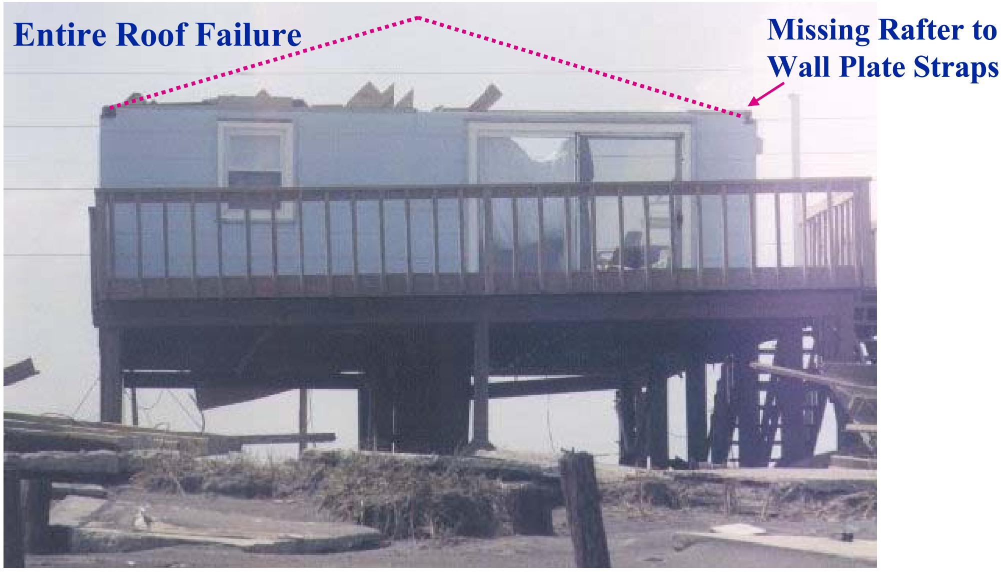


Figure 1-5. Roof Truss/Rafter to Wall Connection

Figure 1-6. Gable End Failure

envelope is breached, the internal pressures build up and increase the likelihood of roof failures. Garage doors (Fig 1-9) and other doors and skylights are also vulnerable to failure. Any glazed opening, unless it is protected or is impact-resistant, is highly vulnerable to failure from flying debris.

Foundation. Wall-to-floor-to-foundation failures are rare in site-built buildings. The most vulnerable houses are low-value buildings that sit atop concrete blocks (Fig. 1-10) and have no uplift or lateral restraint. Houses built on stem walls or slabs

(a) Gable – 1

(b) Gable - 2

(c) Hip - 1

(d) Hip - 2

Figure 1-7. Performance of Same Street Hip and Gable Houses at Navarre Beach During Hurricane Erin

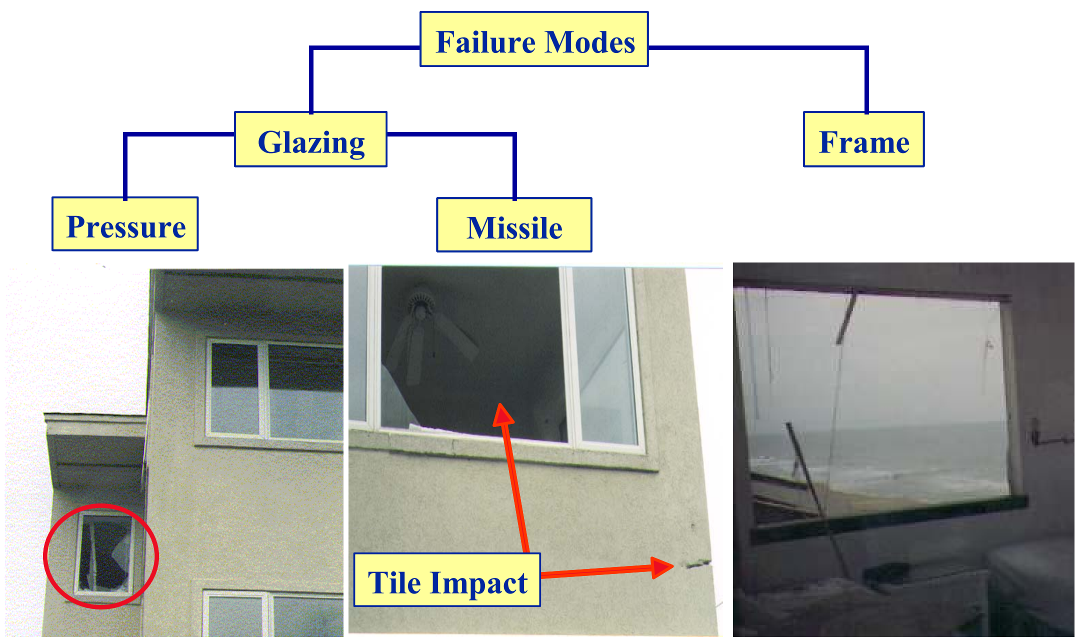


Figure 1-8. Failure Modes for Windows and Openings

Figure 1-9. Garage Door Performance

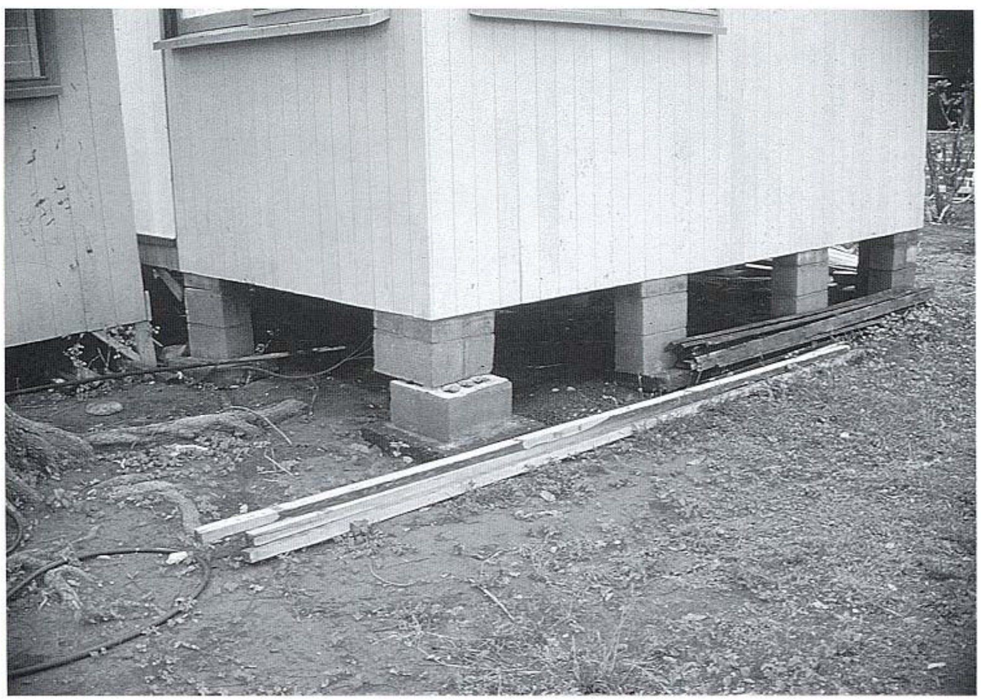


Figure 1-10. Sliding Failure of Foundation– Hurricane Iniki

on grade generally have significant resistance to uplift and lateral forces. They are much more likely to fail in one of the other modes described above. Gravity loads and minimal overturning/sliding resistance is more than adequate to resistance foundation failure of most site-built houses. For houses on piers, bolted or strapped connections designed to carry the loads into the piers generally perform adequately. Foundation failures of site-built houses in hurricanes are almost always caused by storm surge and not wind.

Building Envelope. In summary, for hurricane losses, it is the building envelope that governs insurance wind losses. Figure 1-11 illustrates how the loads increase dramatically once the building envelope fails. Even a small opening, say a small window on a side of a building, can lead to large internal pressures. These pressures act outward on the walls and roof on the leeward and back side of the building and can result in a doubling of the loads on the building envelope. This phenomenon is why the failure of a window often produces a progression of failures in the roof deck, whole roof, or other openings that quickly lead to large insurance losses.

1.7 Organization of Report

Section 2 summarizes the methodology used in this report and presents the locations analyzed within the state. The analysis for existing construction loss relativities is presented in Section 3. The results for new construction to the FBC 2001 are given in Section 4. To use the loss relativities in a rate filing, distributions of the existing building stock are required. Section 5 presents an approach to enable an insurance company to estimate the building stock distribution for its book of business. A summary is presented in Section 6, and Section 7 includes references. Appendices are included that provide background information and details on the technical approach.

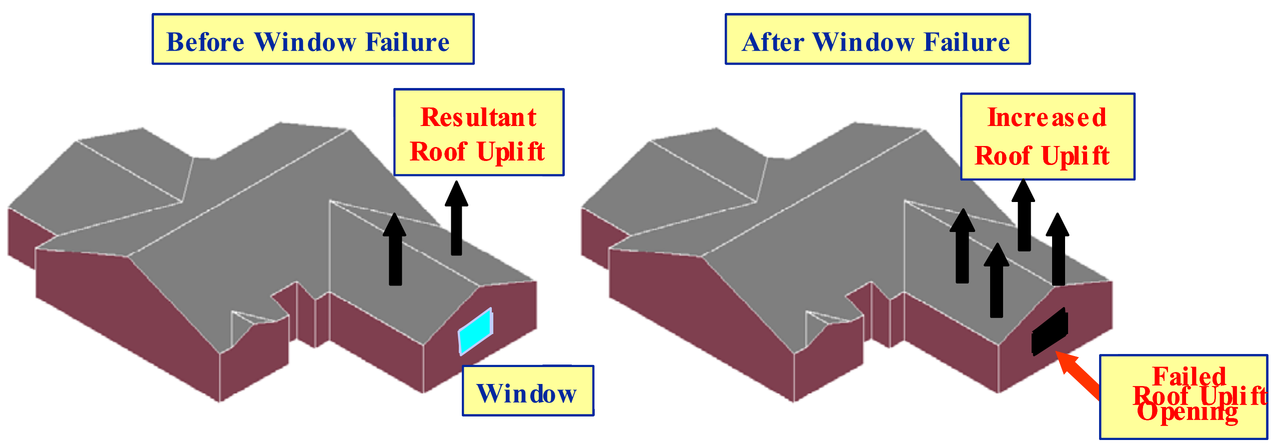


Figure 1-11. Protection of Wall Envelope Reduces Chances of Internal Pressurization

2.0 METHODOLOGY

2.1 Approach

The fundamental approach used herein to develop the loss relativities is to analyze individually-modeled buildings at numerous locations in Florida. Each building is modeled with a specific set of wind-resistive features. The HURLOSS methodology has been used to analyze each modeled building for damage and loss.

The loss costs are estimated for a specified set of insurance parameters: Coverage A (building), C (contents), and D (additional living expenses) limits and deductible. This process is repeated for a large combinatorial set of wind-resistive features for a number of Florida locations (latitude-longitude points).

For each location, the loss relativities are produced by dividing by the loss costs for a selected "central" house. Therefore, the relativities at each location are simply normalized fractions that provide a measure of the differences in loss based on wind resistive features.

The approach used in this study is to develop loss relativities for existing construction (non-FBC 2001) and new construction (FBC 2001) separately. This separation recognizes the changes brought about by the new code and the fact that the methods used to verify that the construction features may be different for existing and new construction. However, for practical reasons, we use a common set of locations in Florida (as described in Section 2.3) to analyze the separate loss relativities for existing and new construction.

As illustrated by the figures in Section 1.4, many key wind features focus on the roof details and openings. Verification of the presence or absence of wind resistive construction features for existing construction, therefore, cannot be practically accomplished without an "inspection". Most such "inspections" can be done in a 20-40 minute period depending on the size of the house and criteria adopted by the insurer. In the absence of an "inspection", there is no reasonably accurate way to "rate" an existing residence for purposes of providing loss mitigation credits or discounts. More discussion on this topic appears in Section 3 and Appendix C.

For new construction, the FBC (Section 1606.1.7) requires the that drawings for new construction summarize key design information. This information should be useful for insurance rating purposes. In addition, insurers may wish to or need to perform an inspection of the building or require documentation from the builder.

2.2 Florida Building Code Wind Regions, Terrains, and Design Options

Figure 2-1 illustrates the wind speed map for the Florida Building Code (FBC 2001, Figure 1606). The wind speed contours start at 100 mph and go to 150 mph.[1] For buildings located between contours, interpolation is allowable for design. In the absence of interpolation between contours, the building will be designed to the higher of the wind speed contours.

2.2.1 Wind-Borne Debris Region

The FBC introduces a Wind-Borne Debris Region where all openings that are not protected with shutters or impact resistant glass

[1] It is possible that some engineers could interpolate to slightly less than 100 mph in the region inside the 100 mph contour since ASCE 7-98 allows interpolation between basic wind contours.

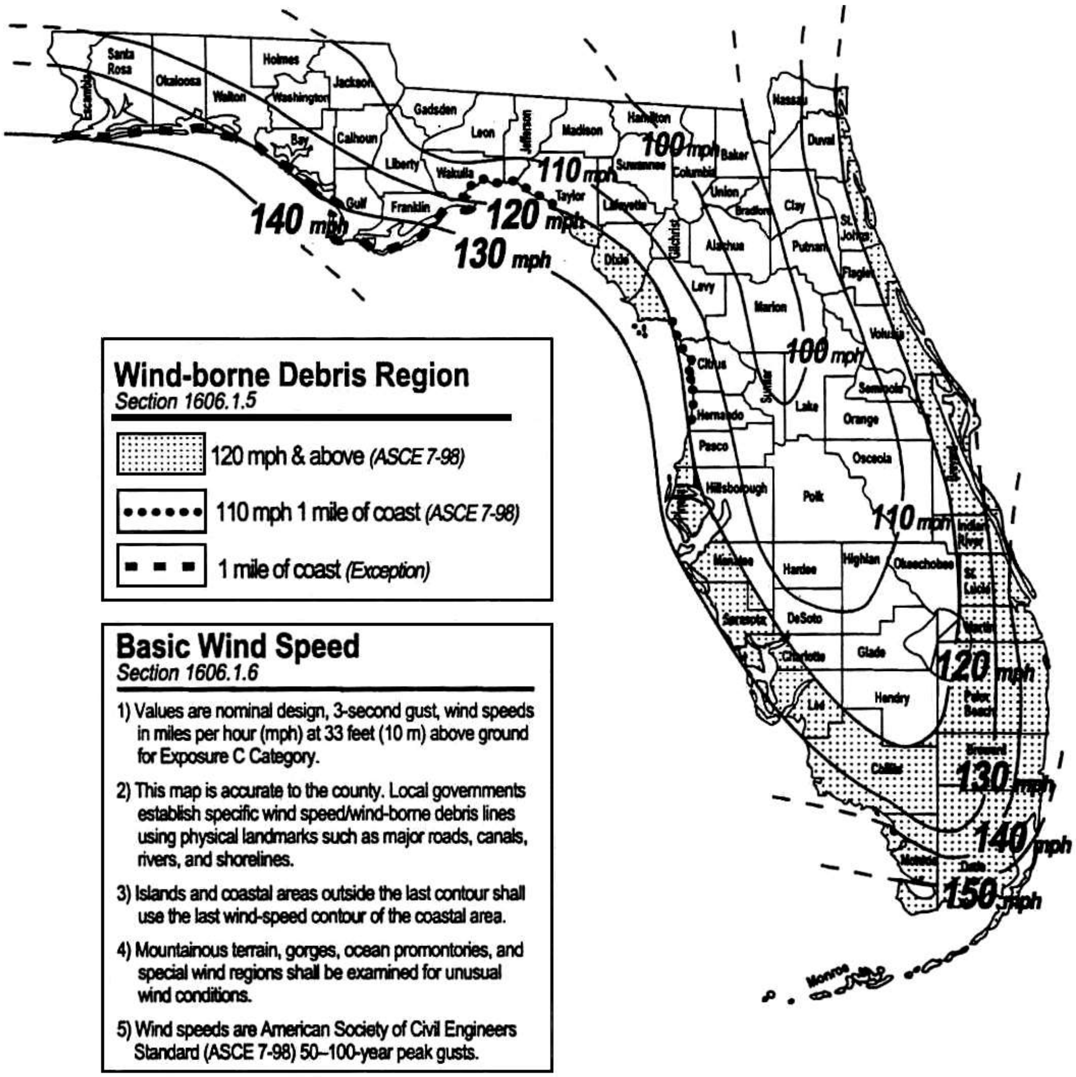


FIGURE 1606
STATE OF FLORIDA
WIND-BORNE DEBRIS REGION & BASIC WIND SPEED

Figure 2-1. Wind Regions in Florida Building Code

are considered to be open. This means a designer has the option of designing the structure as an enclosed building or as a partially enclosed building where the design assumes that wind entering the building adds to the load on the structure.

The Wind-Borne Debris Region (FBC, Section 1606.1.5) includes all areas where the basic wind speed is 120 mph or greater (shaded area of Fig. 2-1) except for the eastern border of Franklin County to the Florida-Alabama line where the region includes areas only within 1 mile of the coast. It also includes areas of Citrus, Hernandes, and Levy Counties that are within 1 mile of the coast (see Fig. 2-1).

2.2.2 Terrain Exposure Category

The Florida Building Code has adopted the Exposure Category (terrain) definitions of ASCE-7 with a few important exceptions (see FBC, Sections 1606.1.8 and 1619.3):

1. Exposure C (open terrain with scattered obstructions) applies to: All locations in HVHZ (Miami-Dade and Broward Counties)
   - Barrier islands as defined per s.161.55(5), Florida Statues, as the land area from the seasonal high water line to a line 5000 ft landward from the Coastal Construction Control line.
   - All other areas within 1,500 ft of the coastal construction control line, or within 1,500 ft of the mean high tide line, whichever is less.
2. Exposure B (urban, suburban, and wooded areas) practically applies to all other locations in Florida by virtue of the exposure definitions for Exposures A and D.

Hence, new residential construction in the state will fall into Exposures B and C. The following paragraphs attempt to provide more background on this important topic as it relates to wind-resistance construction and insurance ratings for buildings.

The effect of terrain (i.e. the reduction in wind speed near the ground produced by the frictional effects of buildings and vegetation) has a significant impact on wind speeds and, hence, wind-induced damage and loss. The magnitude of the reduction of the wind speed at any height is a function of the size and density of the obstructions (buildings, trees, etc). on the ground, as well as the fetch (distance) the wind has blown over a given terrain. The importance of terrain is recognized in most national and international wind loading codes through the use of simplified terrain categories defined, for example, as open terrain, suburban terrain, urban terrain, etc. When designing a building, a design engineer must first determine what terrain a building is going to be built in, and design the building to resist the associated wind loads. In ASCE-7, the national wind loading standard, there is a significant increase in the design loads associated with designing a building located in open terrain (Exposure C) compared to the case of a building designed for suburban terrain conditions (Exposure B). For example, the design loads for the cladding (windows, doors, roof sheathing, etc.) of a 15 ft tall building located in Exposure C are 21% more than those for a building located in Exposure B, and for a 25 foot tall building the difference in the design loads is 34%. The true effect of terrain is in most cases greater than that indicated in the building codes which tend to conservatively underestimate the reduction in wind load that is experienced for most buildings located in suburban terrain.

All damage and loss calculations carried out in this study were performed using terrain models representative of typical terrain Exposure "B" and Exposure "C" conditions.

2.2.3 High Velocity Hurricane Zone

The FBC identifies a High Velocity Hurricane Zone (HVHZ) for Miami-Dade and Broward Counties (FBC, Sections 202 and 1611ff). This portion of the Florida code comes from the South Florida Building Code (SFBC). The HVHZ has some important differences with the non-HVHZ areas of the FBC, including:

1. More stringent missile impact test criteria.
2. Requirement that all doors and non-glazed openings have missile protection.
3. Does not allow for partially enclosed building design.
4. Some restrictions on materials that can be used.
5. Design for Terrain Exposure C conditions.

These requirements make for improved wind resistance for buildings built in the HVHZ.

2.2.4 Design Options

Another key point about the FBC (Section 1606.1) is the allowable use of both performance-based design and prescriptive methods. Performance-based design is based on ASCE 7 loads, and includes options for enclosed and partially enclosed design. In the wind-borne debris region, enclosed designs will have all glazed openings protected for debris impact.

The prescriptive options in the FBC are carried over from the Standard Building Code and include:

1. SBCCI SSTD 10-97, "Standard for Hurricane Resistant Residential Construction"
2. AF&PA, "Wood Frame Construction Manual for One- and Two-Family Dwellings – 1995 SBC High Wind Edition 1996"
3. FC&PA "Guide to Concrete Masonry Residential Construction in High Wind Areas"
4. Wood Products Promotion Council (WPPC) "Guide to Wood Construction in High Wind Areas".

These presumption options are limited to the lower wind speed regions.

Table 2-1 summarizes the design cases for new construction in the Florida Building Code. A "1" in a cell indicates a viable FBC design option for that wind speed. The terrain exposure category was determined by reviewing the FBC definitions for terrain exposure and wind-borne debris regions. As previously discussed, the FBC allows for enclosed building design based on pressure loads only for wind speeds greater than 120 mph in the Panhandle (since the FBC limits the wind-borne debris region in that area to within 1 mile of the coastal mean high water line).

The footnotes in Table 2-1 attempt to explain some of the logic used to develop the table. For example, this table indicates that up to 6 basic designs are possible for a wood frame house on the 120 mph contour in terrain Exposure B.

A key objective of this project is to determine how loss costs vary for the design options for new construction shown in Table 2-1. An important point is that these designs are for the code minimum loads. Many builders will build houses designed for higher wind speeds than dictated by the code. For example, houses can be designed for 130 mph wind speeds in a 120 mph location, etc. Hence, a practical matrix for new construction needs to be expanded beyond the minimal load design. These issues are addressed in Section 4.

2.3 Locations for Loss Relativity Analysis

Table 2-1 shows that there are 12 combinations of wind speed and terrain exposure that result from the Florida Building Code. The first issue for this study is to determine the locations for the analysis of losses for new and existing construction. Since we are normalizing the results at each location by the computed loss costs at that location, the consideration of multiple locations serves to test how the relativities may vary by region within the state.

Once the locations are specified, the relevant new construction building design options (Table 2-1) are located at each point. In addition, the modeled houses for existing construction are also analyzed at each point.

Figure 2-2 shows the selected points for this study. We determined these point locations in the following manner. We roughly allocated the number of points to a contour based on the contour length and spaced the points along the contour. We then used a GIS tool to fine-tune the point locations to the largest town that was on or very near the contour. Again, the reason

Table 2-1. FBC Minimum Load Design Cases (No consideration of topographic speedups)

		FBC: ASCE- 7				FBC Prescriptive Options[7]					
Wind Speed	Terrain Exposure	ASCE 7 Enclosed (non-WBDR)[6]	ASCE 7 Enclosed (WBDR)	ASCE 7 Partially Enclosed	FBC-HVHZ (SFBC)	SBCCI 10[1] Wood/Mas	AFPA[2] Wood Frame	WPPC[3] Wood Fr	FC&PA[4] Masonry	Possible Designs per WF[10] House	Possible Designs per Mas[11] House
100	B[5]	1				1	1	1	1	4	3
110	B[5]	1				1	1	1	1	4	3
120	B	1	1	1		1	1	1	1	6	5
	C		1	1			1			3	2
130	B	1	1	1		1	1	1	1	6	5
	C		1	1						2	2
140	B	1	1	1			1			4	3
	C		1	1						2	2
150	B		1	1						2	2
	C		1	1						2	2
HVHZ-140[8]	C				1					1	1
HVHZ-146[9]	C				1					1	1
Totals[12]		5	8	8	2	4	6	4	4	37	31

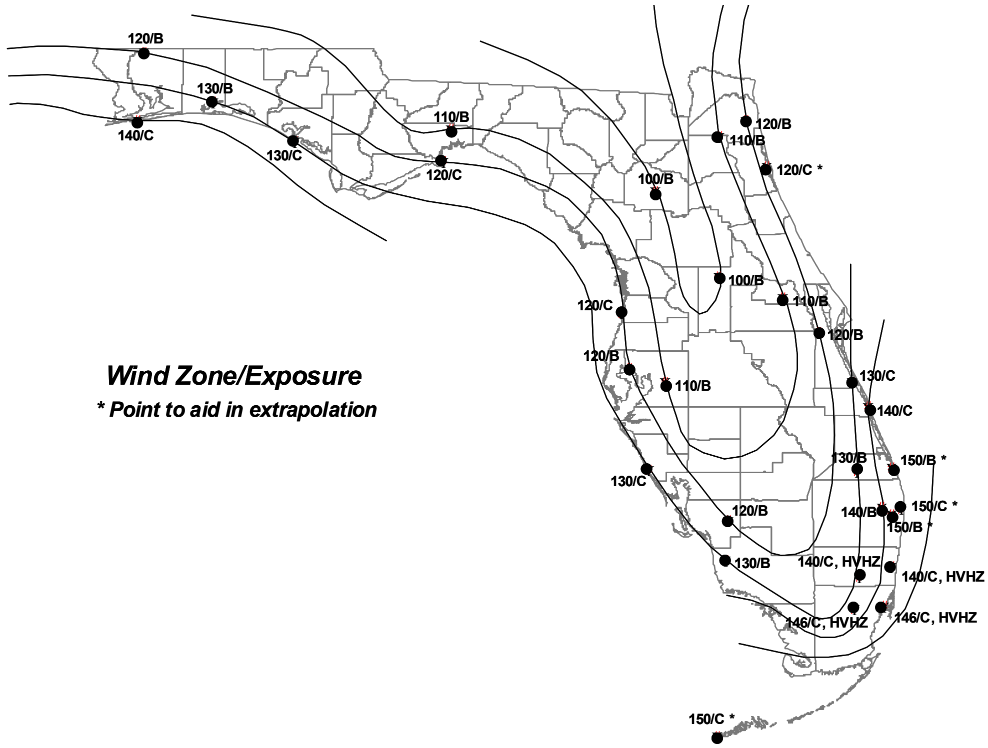
[1] SBCCI SSTD 10 applicable to buildings for basic wind speed of 130 mph or less (Exp B) and 110 mph or less Exp C.
[2] AFPA 1996 High Wind Edition for wood frame for basic wind speed of 146 mph or less (Exp B) and 124 mph or less (Exp C)
[3] Wood Products Promotion Council for wood frame for basic wind speed 130 mph or less (B) and 110 mph or less Exp C
[4] FC&PA Guide to Concrete Masonry Residential Construction in High Wind Areas for basic wind speed of 130 mph or less (Exp B) and 110 mph or less Exp C.
[5] Based on the FBC definitions of Exp C, which is limited to barrier islands and within 1500 ft of the coast, there is no design Exp C for these wind zones
[6] For 120, 130 and 140 mph wind speeds in the Panhandle, the FBC limits the Wind-borne Debris Region (WBDR) to 1 mile from coast.
[7] Per 1606.1.1. Note that these options are not allowed for houses situated on an upper half of an isolated hill, ridge, or escarpment per 1606.1.1.1. Also note that these standards are for enclosed design, hence require wind-borne debris protection in zones 120 and 130 mph.
[8] This corresponds to Broward County.
[9] This corresponds to Miami-Dade County.
[10] WF = Wood Frame
[11] Mas = Reinforced Masonry
[12] Topographic speedups are not considered in the project because Florida has relatively few locations that qualify per ASCE 7-98.

for locating multiple points on a contour is to see if the loss relativities vary much for that contour.[2]

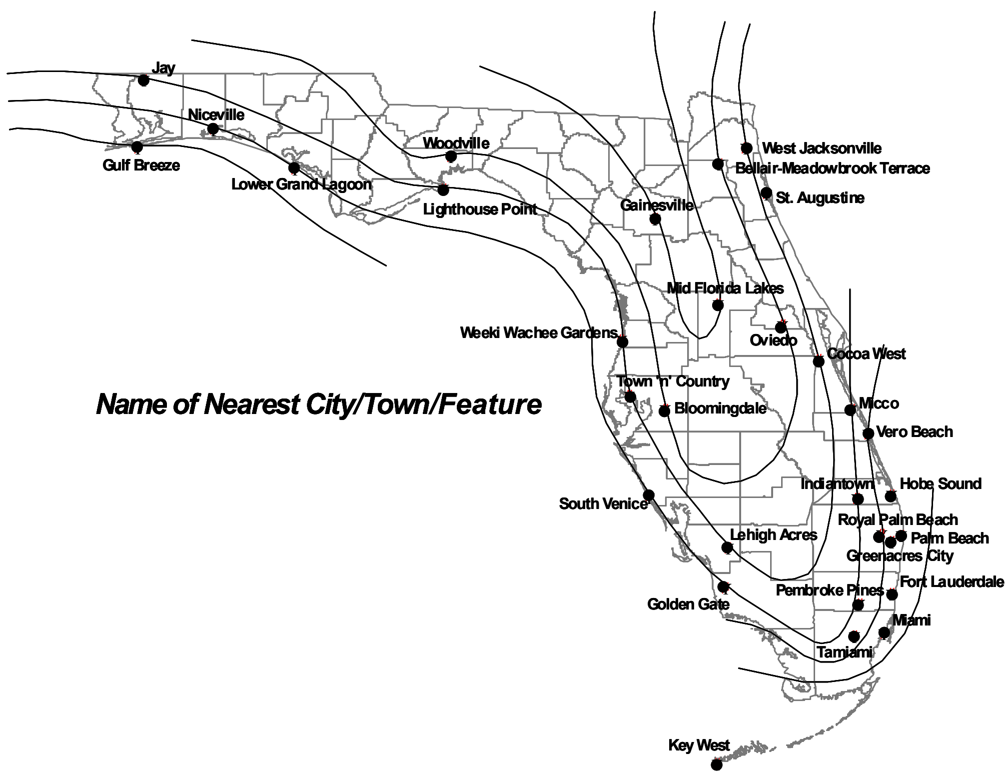
For simplicity, we will use these same locations to develop the loss relativities for existing construction. That is, the locations in Fig. 2-2 are used in the analysis of a class plan for existing houses, as discussed in Section 3.

The location of points on each contour are shown in Fig. 2-2a. For each point, the number denotes the wind speed and the letter denotes the terrain. Points with terrain Exposure C are located within 1500 ft of the coastline. Points not within 1500 ft of the coastline are terrain Exposure B, per the special definitions in the Florida Building Code. Figure 2-2b shows the towns (or geographic feature) where the points are located, or the nearest town. Using the town names to denote

[2] From ASCE 7-98, the contours represent the hurricane winds corresponding to a 500 year return period divided by the square root of the load factor. The contours essentially represent 50-100 year return period wind speeds, with the actual return period determined by the slope of the hurricane wind speed exceedance probability curves for that location.



a. Points Identified by Contour and Terrain Exposure



b. Nearest Towns or Geographic Features for Point Locations

Figure 2-2. Map of Location Points for Loss Relativity Analysis

point locations is simply a way to label the points and does not necessarily imply that the town is exactly on that contour.

Table 2-2 summarizes the 31 points used to define the locations. Note that 9 of the locations are not on a contour. Two each for HVHZ 140 (Broward) and HVHZ 146 (Miami Dade). The design wind speed in these counties is constant over the entire county. The other five points are not on contours. These locations are identified in the comment column in Table 2-2. One of the added points is for 120 mph and the other three are all for the 150 mph wind speed. Since the 150 mph wind speed contour only crosses Florida in the Everglades, we felt it was more appropriate to locate the points on buildable land. This is also consistent with our understanding that there will be no required FBC designs to wind speeds greater than 150 mph.

2.4 HURLOSS Model

ARA's HURLOSS model is summarized in the public domain submittal to the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM). The model was approved by the Commission for the 1999 and 2000 standards and will be submitted in February 2002 for the 2001 standards. The model is used in this study to produce loss costs relativities. Loss costs are not reported in this study since each insurer must perform those calculations for its book of business. The relativities produced herein show how loss costs are expected to vary according to wind resistive features and FBC design options.

The following paragraphs discuss some of the HURLOSS model features relevant to this study. Appendices A and B give additional details.

2.4.1 Simulated Hurricane Wind Climate

For this study, we simulated 300,000 years of hurricanes in the Atlantic Basin and retained all storms that strike Florida. This large number of years was chosen to ensure statistical convergence of loss costs, recognizing that in some cases the difference in modeled buildings could be a change in a single variable out of many variables. Loss costs are driven by the intense storms and 300,000 years produces a sufficient number of intense hurricanes for loss costs convergence.

Figure 2-3 shows several resulting wind speed plots produced from the simulation. Peak gust open-terrain wind speeds are plotted versus return period for four locations: Jay, Miami, Bloomingdale, and Gainesville.

Note that these are open-terrain peak gust 10 m (above ground) wind speeds and are not sustained wind speeds. Also, for typical suburban terrain, the 10 m wind speeds will be notably less.

The simulated wind speed exceedance probabilities are compared to the ASCE 7-98 wind speeds in Fig. 2-4. The small differences are due to the following:

1. The current simulations are based on a larger historical data set, including hurricanes for 1995-2000.
2. The simulations in this study use 300,000 years versus the 20,000 years used for ASCE 7-98 study.
3. Enhancements to the model since 1995.

Nevertheless, the comparisons indicate that the current HURLOSS hurricane model produces similar wind speeds when compared to the national design standards for locations in Florida.

2.4.2 Modeled Buildings

We have used six single-family residential buildings in this study. Table 2-3 summarizes some of the pertinent information on these houses. The six houses include small,

Table 2-2. Location Points and Lat-Long Coordinates

ID	Wind Contour	Exposure	Place	Comment	Label	Latitude (deg) (X_Coord)	Longitude (deg) (Y_Coord)
1	100	B	Gainesville		100/B	-82.35078	29.66851
2	100	B	Mid Florida Lakes		100/B	-81.75630	28.86330
3	110	B	Woodville		110/B	-84.26329	30.24175
4	110	B	Bellair-Meadowbrook Terrace		110/B	-81.75189	30.17602
5	110	B	Oviedo		110/B	-81.15279	28.66395
6	110	B	Bloomingdale		110/B	-82.26102	27.87761
7	120	B	Jay		120/B	-87.14942	30.95997
8	120	B	West Jacksonville		120/B	-81.50699	30.32542
9	120	B	Cocoa West		120/B	-80.82584	28.34633
10	120	B	Lehigh Acres		120/B	-81.66613	26.57927
11	120	B	Town 'n' Country		120/B	-82.59261	28.00821
12	120	C	Lighthouse Point		120/C	-84.33933	29.93707
13	120	C	Weeki Wachee Gardens		120/C	-82.66236	28.52765
14	120	C	St. Augustine	Added point, not on contour	120/C *	-81.31077	29.89192
15	130	B	Niceville		130/B	-86.50246	30.50508
16	130	B	Indiantown		130/B	-80.46272	27.03545
17	130	B	Golden Gate		130/B	-81.68795	26.20149
18	130	C	Lower Grand Lagoon		130/C	-85.73581	30.12823
19	130	C	Micco		130/C	-80.51389	27.87154
20	130	C	South Venice		130/C	-82.40817	27.04785
21	140	B	Royal Palm Beach		140/B	-80.23009	26.70591
22	140	C	Gulf Breeze		140/C	-87.20833	30.32189
23	140	C	Vero Beach		140/C	-80.35962	27.64502
24	150	B	Hobe Sound	Added point, not on contour	150/B *	-80.13952	27.07265
25	150	B	Greenacres City	Added point, not on contour	150/B *	-80.13989	26.62995
26	150	C	Palm Beach	Added point, not on contour	150/C *	-80.03816	26.69286
27	150	C	Key West	Added point, not on contour	150/C *	-81.77521	24.56286
28	140	C	Fort Lauderdale	HVHZ: Broward	140/C, HVHZ	-80.13958	26.14289
29	140	C	Inland Broward County	HVHZ: Broward	140/C, HVHZ	-80.44245	26.05956
30	146	C	Miami	HVHZ: Miami-Dade	146/C, HVHZ	-80.21093	25.77570
31	146	C	Inland Miami Dade County	HVHZ: Miami-Dade	146/C, HVHZ	-80.47958	25.75599

medium, and large floor plans and a range of building values.

Model 0011G is a 1,200 sq ft single story residence with a gable roof and no garage. Figure 2-5a and 2-5b show two wire-frame CAD views of the building. It has a simple rectangular plan, two entry doors, a sliding glass door and eight windows, as shown. The roof pitch is 4:12. The hip roof version (0011H) of this house is identical except for the roof shape (see Fig. 2-5c and 2-5d). The building value is $63,000 for the hip versus $61,000 for the gable, based on an estimate of the increased cost of hip roof versus gable roof construction. Model 0011 is representative of an Economy Building Class house.

Model 0013G, shown in Fig 2-6, is a larger version of 0011 with 1,800 sq ft and a two car garage. The building values are higher, closer to average construction costs. The fenestration area is larger than 0011 because of

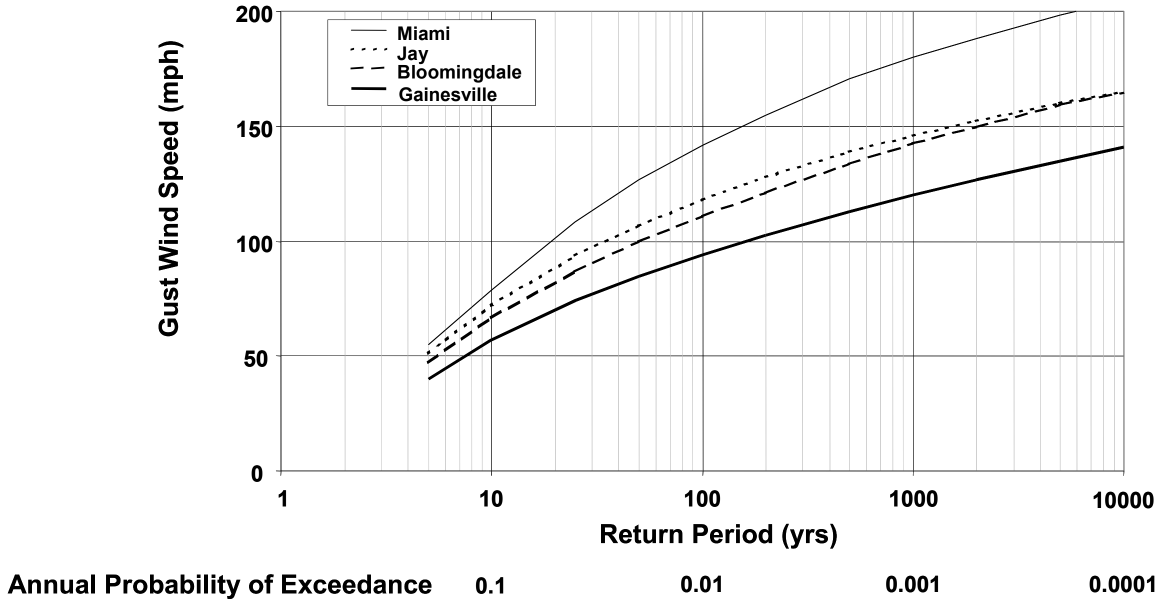


Figure 2-3. Open-Terrain Peak Gust 10 m Wind Speed Plots

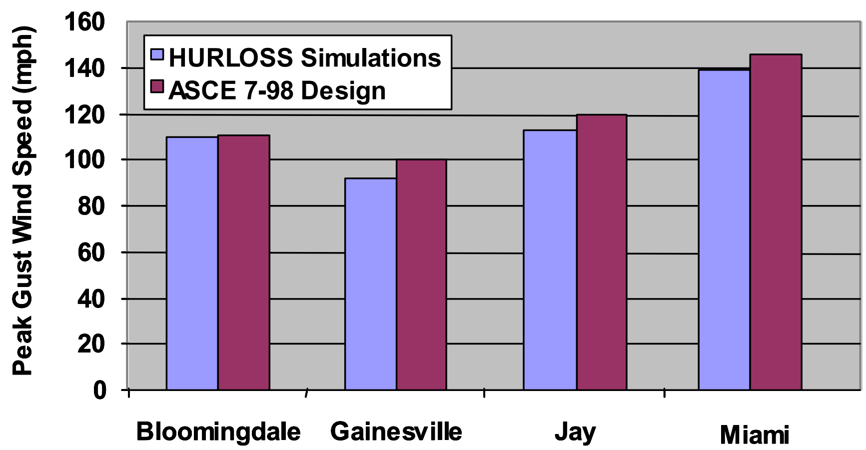


Figure 2-4. Comparisons of Simulated Wind Speeds and ASCE 7-98 Wind Speeds for Comparable Return Periods

the double garage door. The hip roof version (0013H) is estimated to add $5,000 to the cost of the structure.

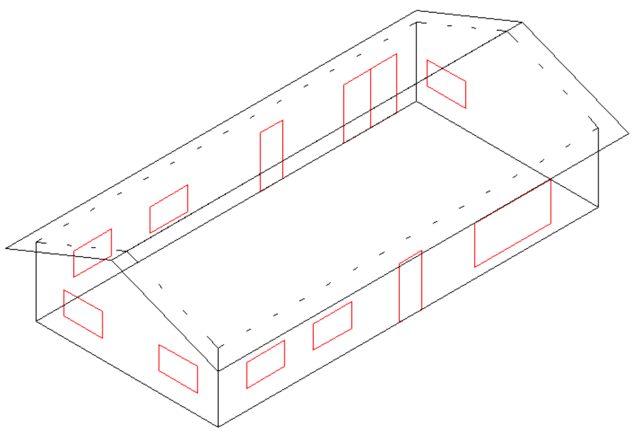
Model 0002 is a higher-end house with more complex geometry and improved finishing details. Figure 2-7 shows the gable and hip versions of this building. The fenestration area includes a two-car garage. There are 3 pairs of sliding glass doors and the resulting percent glazing is 17% of the wall area.

2.4.3 Modeling Approach to Compute Building Damage and Insured Loss

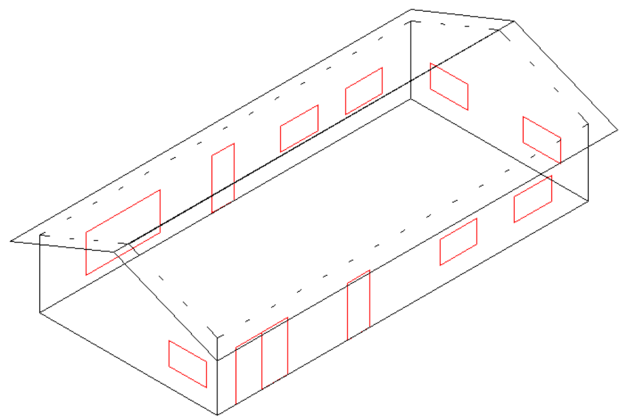
The HURLOSS model is used to compute ground-up losses and insured losses in this study. The HURLOSS modeling approach is shown in Fig. 2-8, which is taken from ARA's submittal to the FCHLPM. The individual building model approach shown in Fig. 2-8a has been used in this study.

Table 2-3. Summary Data for Modeled Buildings

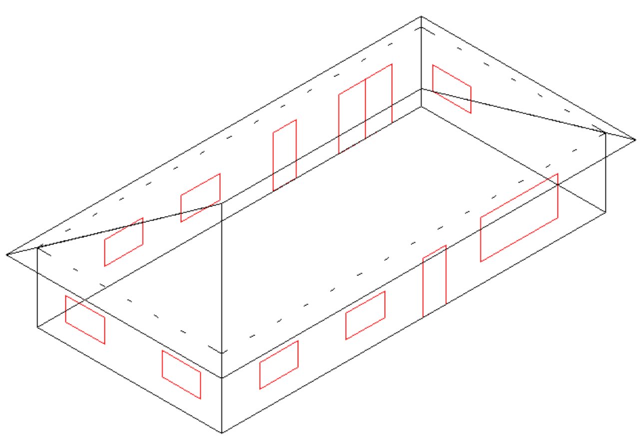
Reference	ARA Model Number	Roof Shape	Garage	% Fenestrations	% Glazing	Plan Sq Ft	Livable Sq Ft	Bldg Value ($)	Value/ Livable Sq Ft ($)
A	0011G	Gable	No	18	15	1200	1200	61,000	50.83
B	0011H	Hip	No	18	15	1200	1200	63,000	52.50
C	0013G	Gable	Yes	26	15	1800	1400	100,000	71.42
D	0013H	Hip	Yes	26	15	1800	1400	105,000	75.00
E	0002G	Gable	Yes	23	17	2534	2050	249,000	121.46
F	0002H	Hip	Yes	23	17	2534	2050	254,000	123.90



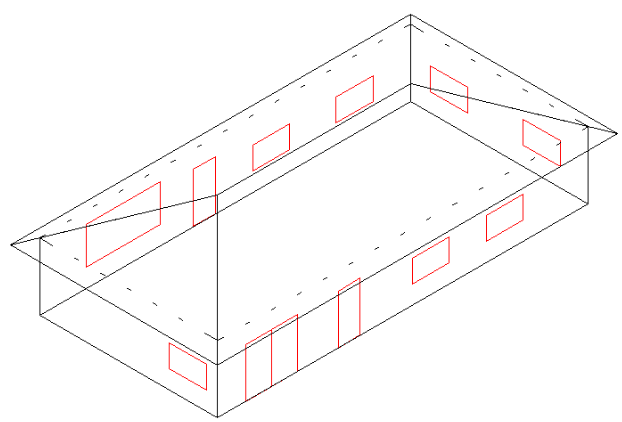
a. Front Isometric View – 0011G



b. Back Isometric View – 0011G

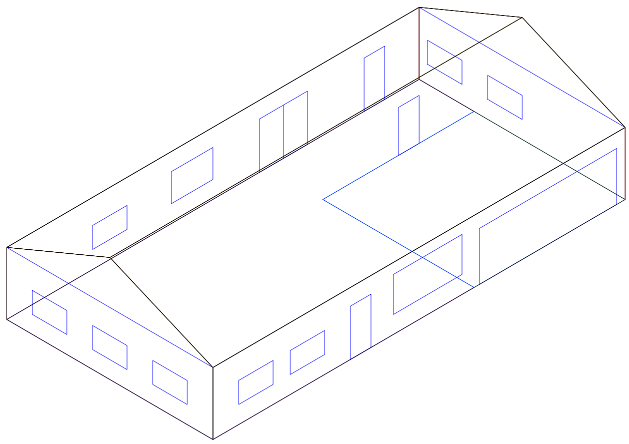


c. Front Isometric View – 0011H

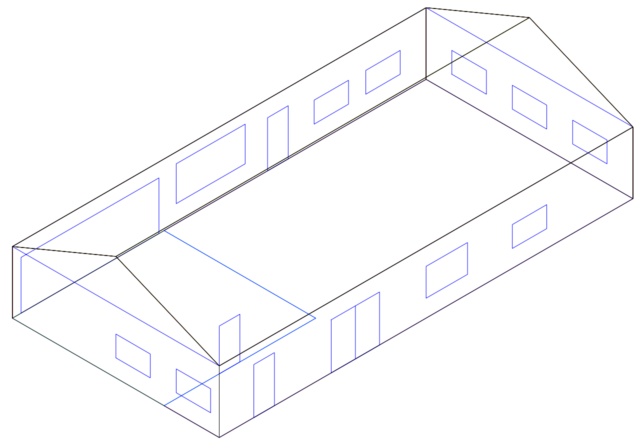


d. Back Isometric View – 0011H

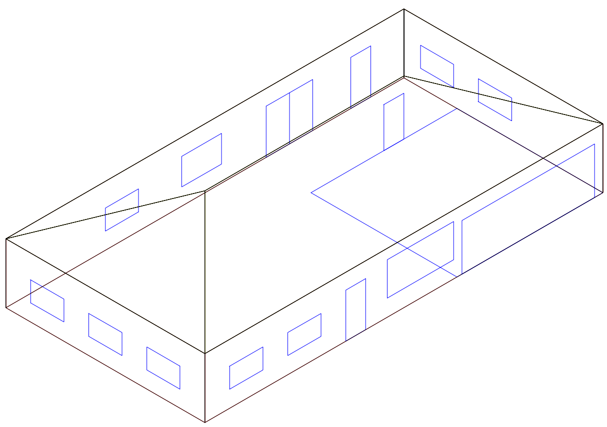
Figure 2-5. Model House 0011 – Gable and Hip



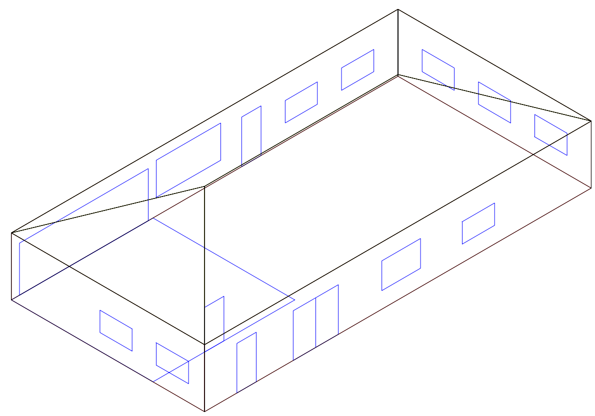
a. Front Isometric View – 0013G



b. Back Isometric View – 0013G



c. Front Isometric View – 0013H

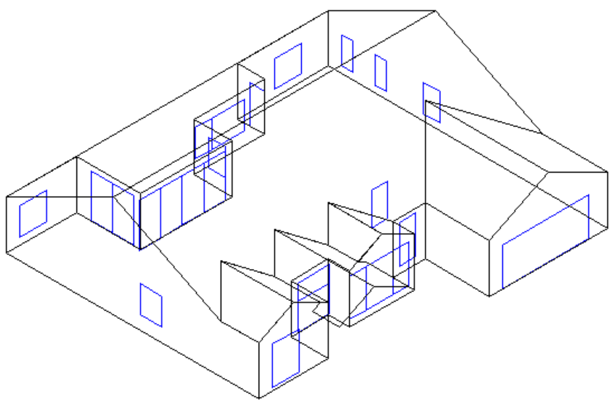


d Back Isometric View – 0013H

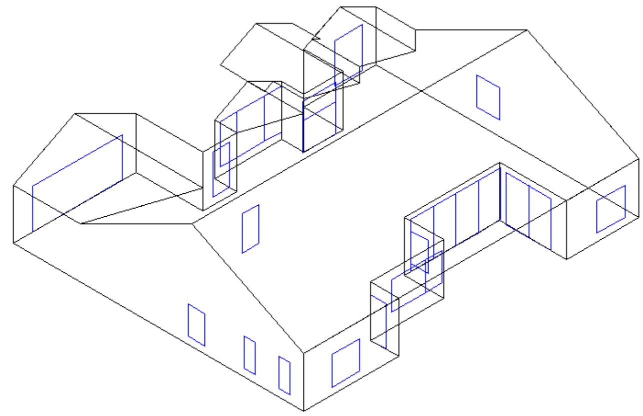
Figure 2-6. Model House 0013 – Gable and Hip

The HURLOSS modeling approach is based on a load and resistance approach which has been validated and verified using both experimental and field data. The model includes the effects of both wind-induced pressures and wind-borne debris on the performance of a structure in a hurricane. The wind loading models replicate the variation of wind loads as a function of direction, and when coupled with a simulated hurricane wind speed trace, a time history of wind loads acting on the building is produced. The wind loading model has been validated through comparisons with wind tunnel data. The time history of wind loads is used in the damage model to account for the progressive damage that often takes place during a hurricane event. The model also allows the effects of nearby buildings and their impact on the loads acting on the exterior of the structure. Appendix B provides additional information on the HURLOSS load and resistance model.

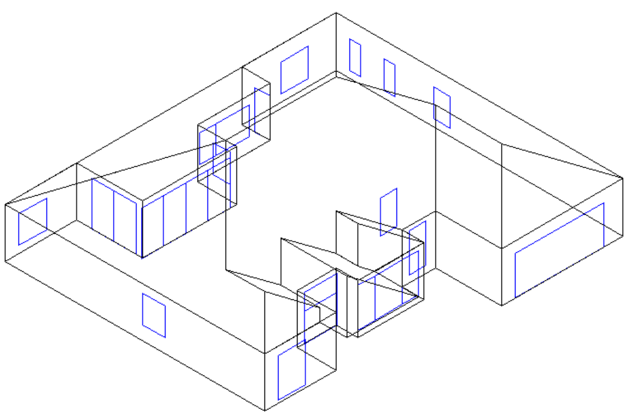
Building Models. The houses are modeled with the geometrical layouts as given in Figs. 2-5, 2-6, and 2-7. Hence, the specific window, door, etc. locations shown in these figures are used in the computation of loads and failures for each individual component.



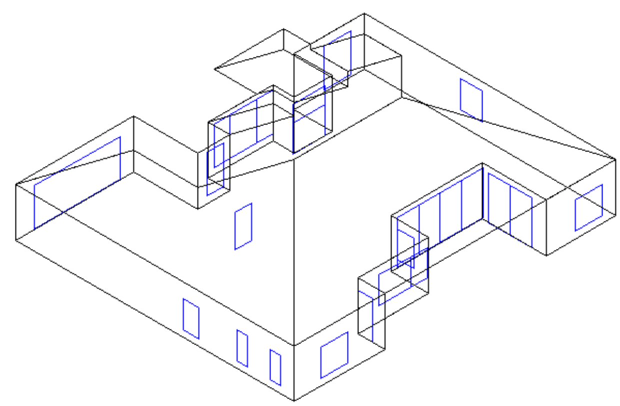
a. Front Isometric View – 0002G



b. Back Isometric View – 0002G



c. Front Isometric View – 0002H

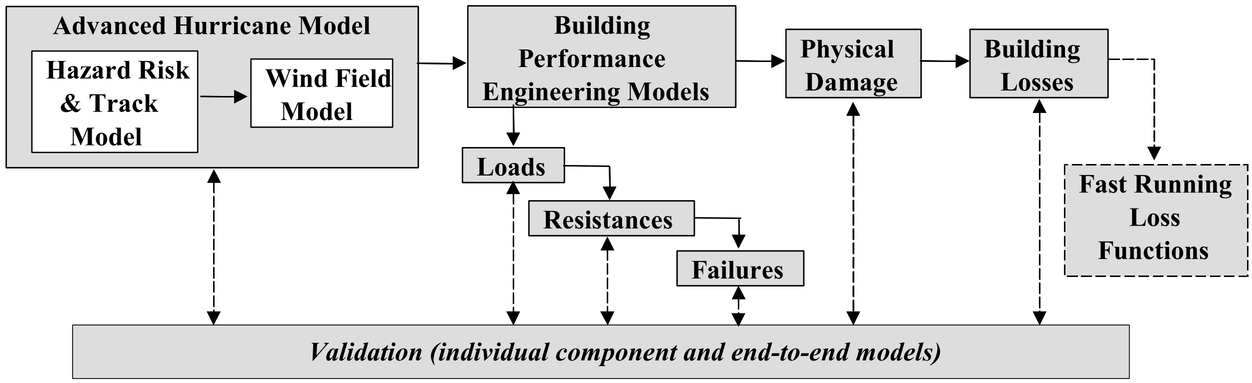


d Back Isometric View – 0002H

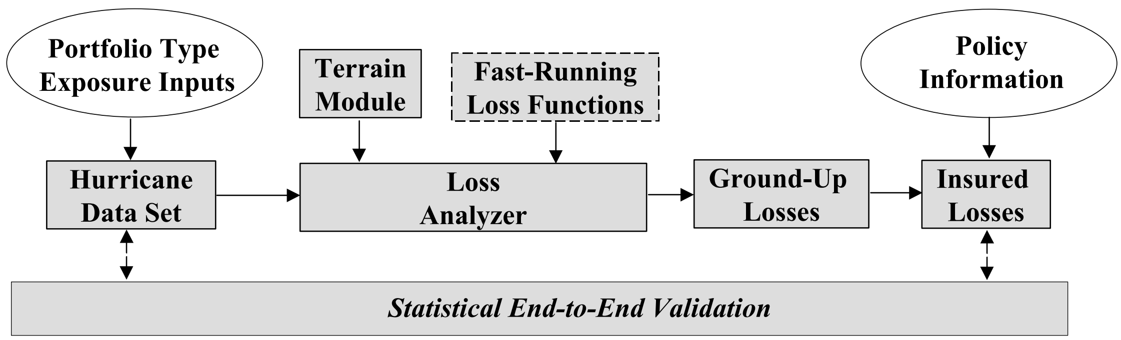
Figure 2-7. Model House 0002 – Gable and Hip

Each of the 6 buildings are located at each point in Florida given in Fig 2-2. In the HURLOSS analysis, the building orientation (with respect to compass direction, N, NE, …) is modeled as uniformly random. That is, for each simulated storm, an orientation is sampled from 0 to 360 degrees and the house is fixed in that orientation for that simulated storm. This approach is used since actual building orientation varies from house-to-house. In general, building orientation is important for a particular storm, but when losses are averaged over all hurricanes, a specific building's orientation generally only affects loss costs by a few percent, particularly in Florida where hurricanes can come from many directions.

The wind resistive features of each house are established for each simulation run of 300,000 years of hurricanes. This is accomplished in the HURLOSS individual risk model by an input file that specifies component and building specifications for each key feature. For example, the roof deck may be specified as ½″ plywood with 8d (2½″) nails at 12″ spacing in the field and 6″ spacing on the plywood edge. HURLOSS lays out the roof deck (see Fig. 2-9) and computes the resistances based on the nail size and spacing. For this example, the resistances are computed using probabilistic models developed from nail pull-out tests. Similarly, if the roof-to-wall



(a) Individual Buildings and Building Class Performance Model



(b) Multiple Site – Multiple Building Loss Projections

Figure 2-8. HURLOSS Modeling Approach for Hurricane Loss Projections

connection is 3-16d (3½″) toe nails, HURLOSS models the uplift resistance of that connection. Hence, each house is modeled with strengths that reflect the specified ultimate wind resistance features for that building.

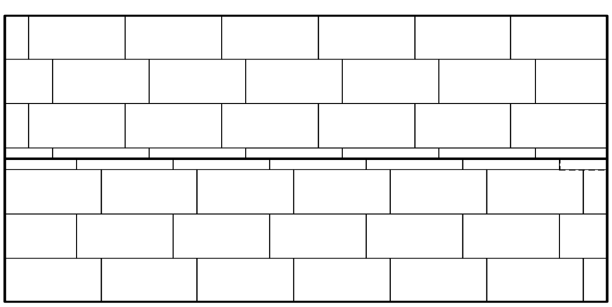


Figure 2-9. Roof Deck Sheathing Layout for House Model 0011G

At each time step during a simulated storm, the computed wind loads acting on the building and its components are compared to the modeled resistances of the various components. If the computed wind load exceeds the resistance of the component, the component fails. When a component such as a window or a door fails, the wind-induced pressure acting on the exterior of the component is transmitted to the interior of the building. This internal pressure is then added (or subtracted) from the wind loads acting on the exterior of the building to determine if any additional components have been overloaded because of the additional loads produced by the internal pressurization of the building.

The progressive failure damage modeling approach is summarized in Fig. 2-10. Estimates of wind loads as a function of wind direction are produced for building components, including roof cover, roof sheathing, windows and doors, as well as for larger components including the entire roof, walls and overturning or sliding of the entire building in cases where a positive attachment to the ground does not exist.

The statistical properties of the resistances of the building components are obtained from laboratory tests and/or engineering calculations. In the simulation process, the resistances of the individual building components that will be loaded are sampled prior to the simulation of a hurricane, and are held constant throughout the simulation. The model computes a complete history of the failure of the building, which can be used to make a "movie" of the building performance.

Once the building damage has been computed for a given storm and the losses for all coverages computed, the process is repeated for a new set of sampled building component resistances. Once a large number of simulations have been performed, we have derived the data necessary to develop a statistical model for the expected performance of the building given the occurrence of a storm.

With this explicit modeling approach, it is possible to assess the impact of the Florida Building Code on the reduction in physical damage and insured loss. For example, the analysis of enclosed designs (protected openings) and partially-enclosed designs can be explicitly modeled in the same manner an engineer designs the truss package or the builder selects the windows to comply with the required dynamic pressure rating.

Appendix B further describes the wind load and debris models that are part of the HURLOSS methodology.

2.4.4 Insurance Assumptions

Table 2-8 summarizes the insurance coverage and deductibles treated in this project. The sensitivity of the results to Coverage C limits and a method to interpolate for other deductibles are described in Section 3.

The repair and reconstruction cost estimations follow the requirements of Chapter 34 of the Florida Building Code 2001.

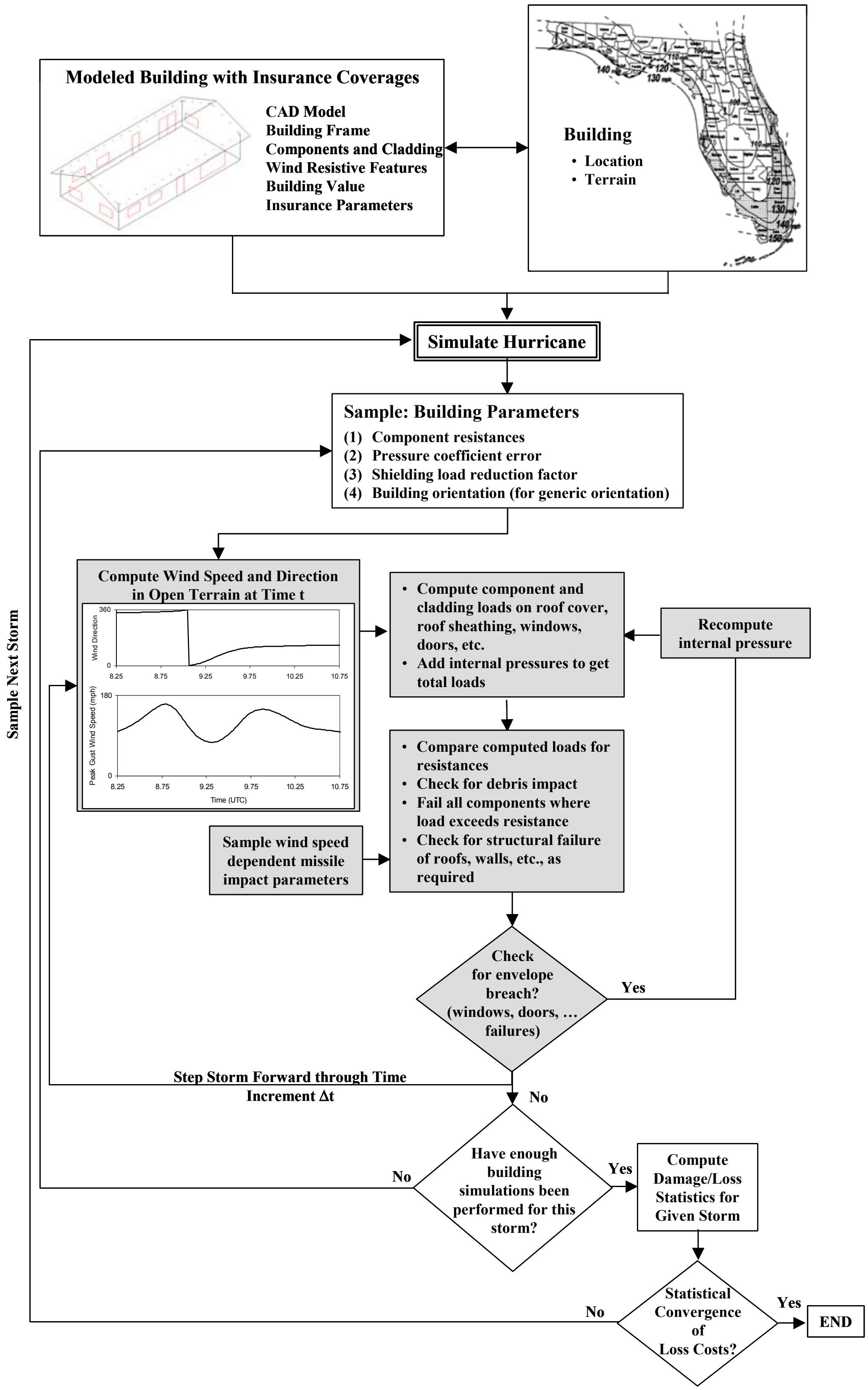


Figure 2-10. HURLOSS Building Damage Simulation Methodology

Table 2-8. Insurance Parameters

House	Coverage A Limit ($)	Coverage C (% of A)	Coverage D (% of A)	Deductibles (% of Total)
0011G	63,000	50 and 70	20	0, 2, and 5
0011H	65,000	50 and 70	20	0, 2, and 5
0013G	100,000	50 and 70	20	0, 2, and 5
0013H	105,000	50 and 70	20	0, 2, and 5
0002G	249,000	50 and 70	20	0, 2, and 5
0002H	254,000	50 and 70	20	0, 2, and 5

3.0 LOSS RELATIVITIES FOR EXISTING CONSTRUCTION

3.1 General

The key construction features for single family houses that influence hurricane losses were introduced in Section 1.0. This section presents the analysis of key wind mitigation features of existing residential construction that influence physical damage and loss in a hurricane. Existing construction refers to all site-built single family buildings built to any code or standard other than the 2001 Florida Building Code.

A main consideration for the rating of existing buildings is method of verification. In general, design documentation is not readily available for existing single family site-built houses. Therefore, any classification feature must be determinable by a site survey or inspection. Features that cannot be readily verified are not good candidates for a rating plan for existing single family houses.

Table 3-1 summarizes the wind-resistive features modeled in the analysis of loss relativities. The primary rating factors are given in the top half of the table. The variables in the shaded area are secondary rating factors. Each wind-resistive feature can be analyzed for several distinct "categories", where each category corresponds to a characteristic method of construction. For example, the roof-to-wall connection is assumed to be: (1) toe nail, (2) clip, (3) wrap, or (4) double-wrap strap connection. These four categories are chosen from a near continuum of possibilities and are categorized into a few distinct cases for practical reasons.

Discussion of verification/inspection issues with respect to each wind-resistive feature is presented in Appendix C. Appendix C also discusses the analysis and presents plots of loss relativity versus location.

As discussed in Appendix C, opening protection can be achieved in several ways, including the use of impact resistant glazing, impact resistant coverings, and also wood structural panels, per the FBC.[1] We note that this study has not analyzed wood structural panels (plywood shutters) because of the limited time and scope of this effort and the need for detailed analysis of test data to properly characterize the impact and pressure cycling resistances of wood panels. We have also not attempted to quantify any added benefits provided by passive in-place protection afforded by impact resistant glazing.[2]

There are some important differences in the variables in Table 3-1 and those in the pioneering FWUA Class Plan. The main differences are:

1. Treatment of FBC Terrain Categories
2. Treatment of FBC Roof Coverings
3. More categories for Roof-to-Wall Connections
4. Additional categories for Roof Deck Attachment
5. Opening protection for glazed openings only, per FBC in non-HVHZ
6. Consideration of Wall-to-Foundation Connection.

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[1] For non-HVHZ locations in Florida, wood structural panels can be used for protection of openings without meeting the impact and pressure cycling test requirements. See FBC Section 1606.1.4 for wood panel fastening requirements.

[2] Glazing refers to glass or transparent or translucent plastic sheet used in windows, doors, or skylights (ASCE 7-98, Section 6.2).

Table 3-1. Existing Construction Classification Variables

Basic Feature	Categories	General Description
Primary Rating Factors		
1. Terrain	2	FBC Terrain B, FBC Terrain C
2. Roof Shape	2	Hip, Other
3. Roof covering	2	FBC equivalent, non-FBC equivalent
4. Secondary Water Protection	2	No, Yes
5. Roof-to-Wall Connection	4	Toe Nail, Clip, Wrap, Double Wrap
6. Roof Deck Material/Attachment	5	Plywood/OSB (3 nail size/spacings), Dimensional Lumber, Reinforced Concrete
7. Openings: Protection Level	3	None, Basic, SFBC/SSTD 12/ASTM E 1996
Secondary Rating Factors		
1. Openings: Protection Coverage	2	All Openings Protected, Only Glazed Openings Protected
2. Gable End Bracing	2	No, Yes
3. Wall Construction	3	Frame, Masonry, Reinforced Masonry
4. Wall-to-Foundation Restraint	2	No, Yes

These differences make the classes for existing construction more consistent with the FBC. This is important since mitigation (such as new roof covers, opening protection, etc.) of these houses must comply with the requirements of the FBC.

Section 3.2 provides the resulting loss relativity tables for the primary rating variables. Section 3.3 provides the results for the secondary rating variables. Section 3.4 presents building component failure rate data and discusses the relative difference in performance of houses with different relativities. Section 3.5 presents the analysis for different deductibles.

3.2 Primary Relativity Tables

The main loss relativity tables are given in Tables 3-2 and 3-3 for FBC Terrain B and C, respectively. The rating factors are discussed in Appendix C. These tables are normalized to a “central” house, as discussed in Section 3.4. These tables are for 2% deductible. The use of these tables for other deductibles is discussed in Section 3.5.

The loss relativities in Table 3-2 for Terrain B are based on averaging the loss relativities for each of three modeled houses for all 17 Terrain B locations in Table 2-2.

There are 14 Exposure C locations in Table 2-2. These locations are intended to represent:

1. Points located within 1500 feet of coast line.
2. Barrier islands.
3. All of Broward and Dade counties, per the FBC.

The relativities in Table 3-3 for these Terrain C locations are based on averaging the 14 modeled Terrain C locations across the state.

Because Terrain Category C loss costs are higher than Terrain Category B loss costs, the normalizing base class loss costs are different for Tables 3-2 and 3-3. Therefore, although the range in relativities is larger for Terrain C, the base loss costs for these locations are higher, reflecting the open terrain exposure.

Table 3-2. Loss Costs Relativities – Terrain B Locations with 2% Deductible

Terrain Category B – 2% Deductible				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A	Toe Nails	None	2.37	2.22	1.26	1.18
			Basic	1.53	1.37	0.91	0.83
			Hurricane	1.33	1.15	0.80	0.71
		Clips	None	1.55	1.37	0.91	0.80
			Basic	1.26	1.08	0.75	0.65
			Hurricane	1.19	1.01	0.72	0.61
		Single Wraps	None	1.53	1.35	0.91	0.79
			Basic	1.25	1.07	0.75	0.65
			Hurricane	1.19	1.00	0.72	0.61
		Double Wraps	None	1.53	1.35	0.91	0.80
			Basic	1.25	1.07	0.75	0.65
			Hurricane	1.19	1.00	0.72	0.61
	B	Toe Nails	None	2.16	2.05	1.22	1.14
			Basic	1.27	1.17	0.88	0.81
			Hurricane	1.04	0.92	0.76	0.68
		Clips	None	**1.00**	0.84	0.76	0.64
			Basic	0.84	0.71	0.65	0.56
			Hurricane	0.80	0.66	0.63	0.55
		Single Wraps	None	0.95	0.76	0.75	0.64
			Basic	0.79	0.64	0.64	0.55
			Hurricane	0.77	0.63	0.63	0.55
		Double Wraps	None	0.94	0.76	0.75	0.64
			Basic	0.79	0.63	0.64	0.55
			Hurricane	0.77	0.62	0.63	0.55
	C	Toe Nails	None	2.15	2.04	1.22	1.15
			Basic	1.27	1.16	0.88	0.81
			Hurricane	1.03	0.92	0.75	0.68
		Clips	None	0.98	0.82	0.75	0.64
			Basic	0.82	0.70	0.64	0.56
			Hurricane	0.78	0.66	0.63	0.55
		Single Wraps	None	0.91	0.73	0.75	0.63
			Basic	0.77	0.63	0.64	0.55
			Hurricane	0.75	0.62	0.63	0.55
		Double Wraps	None	0.90	0.72	0.75	0.63
			Basic	0.75	0.61	0.64	0.55
			Hurricane	0.74	0.61	0.63	0.54
FBC Equivalent	A	Toe Nails	None	2.11	2.05	1.07	1.04
			Basic	1.26	1.22	0.71	0.69
			Hurricane	1.03	0.99	0.59	0.57
		Clips	None	1.22	1.19	0.67	0.65
			Basic	0.94	0.91	0.53	0.51
			Hurricane	0.88	0.84	0.49	0.47
		Single Wraps	None	1.21	1.18	0.67	0.65
			Basic	0.94	0.90	0.53	0.51
			Hurricane	0.87	0.84	0.49	0.47
		Double Wraps	None	1.21	1.17	0.67	0.65
			Basic	0.93	0.90	0.53	0.51
			Hurricane	0.87	0.83	0.49	0.47
	B	Toe Nails	None	1.95	1.90	1.03	1.01
			Basic	1.06	1.02	0.69	0.67
			Hurricane	0.80	0.78	0.56	0.55
		Clips	None	0.72	0.69	0.53	0.50
			Basic	0.59	0.56	0.44	0.42
			Hurricane	0.54	0.51	0.43	0.41
		Single Wraps	None	0.65	0.61	0.52	0.50
			Basic	0.53	0.49	0.43	0.41
			Hurricane	0.51	0.48	0.43	0.41
		Double Wraps	None	0.65	0.60	0.52	0.50
			Basic	0.52	0.48	0.43	0.41
			Hurricane	0.51	0.47	0.43	0.41
	C	Toe Nails	None	1.94	1.89	1.03	1.01
			Basic	1.05	1.02	0.69	0.67
			Hurricane	0.80	0.77	0.56	0.55
		Clips	None	0.70	0.67	0.52	0.50
			Basic	0.58	0.55	0.44	0.42
			Hurricane	0.53	0.51	0.43	0.41
		Single Wraps	None	0.62	0.58	0.52	0.49
			Basic	0.51	0.48	0.43	0.41
			Hurricane	0.49	0.47	0.42	0.41
		Double Wraps	None	0.61	0.57	0.52	0.49
			Basic	0.50	0.46	0.43	0.41
			Hurricane	0.49	0.46	0.42	0.41

Notes: 1. This table is based on averaging the relativities for each of the three modeled houses (with composition shingle roof coverings) for all 17 Terrain B locations.
2. This table applies to single family houses in Terrain B except those with a reinforced concrete roof deck.
3. Secondary factors are not considered in this table, including: (i) board roof decks (dimensional lumber and tongue and groove); (ii) masonry walls and reinforced masonry walls; (iii) all openings protected versus just glazed opening protected; (iv) unbraced gable end for gable roofs (other roof shape); and (v) unrestrained foundation.

Table 3-3. Loss Costs Relativities – Terrain C Locations with 2% Deductible

Terrain Category C – 2% Deductible				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A	Toe Nails	None	1.60	1.49	1.16	1.09
			Basic	1.13	0.99	0.71	0.61
			Hurricane	0.98	0.83	0.57	0.45
		Clips	None	1.31	1.19	0.89	0.79
			Basic	0.99	0.83	0.58	0.45
			Hurricane	0.90	0.73	0.51	0.38
		Single Wraps	None	1.28	1.15	0.88	0.78
			Basic	0.97	0.81	0.58	0.45
			Hurricane	0.90	0.73	0.51	0.38
		Double Wraps	None	1.27	1.15	0.88	0.78
			Basic	0.97	0.81	0.58	0.45
			Hurricane	0.90	0.73	0.51	0.38
	B	Toe Nails	None	1.46	1.37	1.13	1.07
			Basic	0.89	0.80	0.65	0.58
			Hurricane	0.72	0.62	0.50	0.42
		Clips	None	**1.00**	0.89	0.69	0.56
			Basic	0.60	0.47	0.43	0.33
			Hurricane	0.49	0.35	0.39	0.28
		Single Wraps	None	0.84	0.68	0.64	0.47
			Basic	0.53	0.38	0.41	0.30
			Hurricane	0.48	0.32	0.38	0.28
		Double Wraps	None	0.79	0.59	0.63	0.45
			Basic	0.51	0.34	0.41	0.29
			Hurricane	0.47	0.31	0.38	0.27
	C	Toe Nails	None	1.45	1.37	1.13	1.07
			Basic	0.88	0.79	0.65	0.58
			Hurricane	0.71	0.62	0.50	0.42
		Clips	None	0.98	0.88	0.69	0.56
			Basic	0.57	0.46	0.43	0.33
			Hurricane	0.46	0.34	0.38	0.28
		Single Wraps	None	0.81	0.64	0.63	0.44
			Basic	0.49	0.36	0.40	0.29
			Hurricane	0.43	0.30	0.38	0.27
		Double Wraps	None	0.72	0.47	0.62	0.41
			Basic	0.45	0.30	0.39	0.27
			Hurricane	0.42	0.28	0.37	0.26
FBC Equivalent	A	Toe Nails	None	1.49	1.44	1.07	1.03
			Basic	0.97	0.93	0.59	0.56
			Hurricane	0.81	0.77	0.43	0.40
		Clips	None	1.16	1.12	0.75	0.73
			Basic	0.80	0.76	0.43	0.39
			Hurricane	0.71	0.67	0.36	0.32
		Single Wraps	None	1.12	1.09	0.75	0.72
			Basic	0.79	0.74	0.43	0.39
			Hurricane	0.71	0.66	0.36	0.32
		Double Wraps	None	1.12	1.08	0.75	0.72
			Basic	0.78	0.74	0.43	0.39
			Hurricane	0.71	0.66	0.36	0.32
	B	Toe Nails	None	1.36	1.32	1.04	1.01
			Basic	0.78	0.75	0.55	0.53
			Hurricane	0.60	0.57	0.38	0.36
		Clips	None	0.87	0.84	0.54	0.51
			Basic	0.46	0.42	0.31	0.28
			Hurricane	0.35	0.30	0.26	0.23
		Single Wraps	None	0.68	0.63	0.46	0.41
			Basic	0.38	0.33	0.28	0.24
			Hurricane	0.32	0.27	0.26	0.22
		Double Wraps	None	0.60	0.53	0.45	0.39
			Basic	0.35	0.29	0.27	0.23
			Hurricane	0.32	0.26	0.25	0.22
	C	Toe Nails	None	1.36	1.32	1.04	1.01
			Basic	0.78	0.74	0.55	0.53
			Hurricane	0.59	0.56	0.39	0.36
		Clips	None	0.86	0.83	0.54	0.50
			Basic	0.44	0.41	0.30	0.27
			Hurricane	0.32	0.29	0.26	0.23
		Single Wraps	None	0.64	0.59	0.45	0.39
			Basic	0.35	0.31	0.27	0.23
			Hurricane	0.29	0.25	0.25	0.22
		Double Wraps	None	0.51	0.41	0.43	0.36
			Basic	0.30	0.25	0.26	0.22
			Hurricane	0.28	0.23	0.25	0.21

Notes: 1. This table is based on averaging the relativities for each of the three modeled houses (with composition shingle roof coverings) for all 14 Terrain C locations.
2. This table applied so single family houses in Terrain C except those with a reinforced concrete roof deck.
3. Secondary factors are not considered in this table, including: (i) board roof decks (dimensional lumber and tongue and groove); (ii) masonry walls and reinforced masonry walls; (iii) all openings protected versus just glazed opening protected; (iv) unbraced gable end for gable roofs (other roof shape); and (v) unrestrained foundation.

Appendix C discusses the analysis and shows how the relativities vary by location for a range of houses. The variation in relativity was not judged to be significant enough to warrant the complexities introduced by separate relativities for each location. The difference in relativities for different contents ratios was also insignificant, as illustrated in Appendix C.

Some simplifications in Table 3-2 for Terrain B tables can be made by dropping the "Double Wrap" level in the "Roof-Wall Connection" column. There is little difference in these relativities and those of the "Single Wrap". For Terrain C, there is a clear difference between Single and Double Wrap relativities for the stronger houses. To keep the formats identical, we therefore left the "Double Wrap" level in Table 3-2 for this report.

3.3 Sensitivity Studies on Secondary Rating Variables

The following wind resistive features were analyzed in separate loss relativity sensitivity studies because of the number of computer runs required in a full combinatorial analysis:

1. Roof Deck Attachment D (Dimensional Lumber, etc.)
2. Wall Construction
3. Reinforced Concrete Roof Deck
4. Opening Coverage
5. Gable End Bracing
6. Foundation Restraint.

These results are reported in the following paragraphs.

We note that some of these factors result in very minor adjustments to the relativities. The results of the analysis of these factors are included for completeness. Reinforced Concrete Roof Deck requires a separate table because of the much higher levels of roof strength.

3.3.1 Deck Attachment D

Deck Attachment D includes primarily dimensional lumber and tongue and groove decks. It may also include plywood decks attached with high capacity screws, etc. Basically, this category is for deck attachment method that exceeds a mean uplift capacity of 338 psf (see Appendix C).

Dimensional Lumber (or Tongue and Groove) decks were analyzed for two locations, two house models (0011 and 0013), hip and gable roof shapes, and for a weak, moderate, and strong house. These houses are identified in Table 3-4. For example, the weak houses (House A) had non-FBC shingles, 6d nail roof deck attachment, toe nailed roof-to-wall connection, no opening protection, and no secondary water resistance. Both gable and hip houses were analyzed for weak, moderate, and strong cases.

The dimensional lumber results map very closely to Deck Attachment C in the relativity tables. The average difference is about a 4% reduction. That is, for a house with a dimensional lumber or tongue and groove board deck (with 2 nails per board), use the appropriate relativity (R) for Deck Attachment C, based on the house features in Table 3-2 or 3-3. Then adjust that relativity by

$$R' = 0.96\,R \quad . \qquad (3\text{-}1)$$

Other deck attachments that produce uplift resistances greater than 338 psf, based on laboratory tests, should also be rated as Category D.

3.3.2 Wall Construction

Masonry and reinforced masonry walls were analyzed for the houses in Table 3-4. Masonry wall houses were found to perform similar to wood frame houses but experience slightly fewer wall failures. Reinforced masonry walls perform better than unreinforced

Table 3-4. Houses Used for Sensitivity Studies on Secondary Rating Variables

				Roof Shape			
				Other		Hip	
Roof Covering	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	House A-G		House A-H	
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None	House B-G		House B-H	
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane	House C-G		House C-H	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				

walls since they do not fail due to uplift forces that act on the roof-to-wall connection. The appropriate house relativity should be adjusted by

$$R' = 0.98R \text{ , Unreinforced Masonry}$$
$$R' = 0.95R \text{ , Reinforced Masonry} \quad (3\text{-}2)$$

That is, the appropriate relativity is found in Table 3-2 or 3-3, based on the house features. Then the relativity is adjusted by Eqn. 3-2. For example, for a reinforced masonry wall, House B-H in Terrain B for 2% deductible (Table 3-2):

$$R' = 0.95(0.76) = 0.72 \ . \quad (3\text{-}3)$$

Note that this adjustment does not reflect the roof-to-wall connection, which is rated separately.

3.3.3 Reinforced Concrete Roof Deck

A reinforced masonry wall house with a reinforced concrete roof deck performs better than the strongest house in the loss relativity tables. These houses have both roof strength, mass, and secondary water resistance. They perform extremely well in high wind speeds. If these buildings have impact protected openings, the roof covering is generally the only weakness of these structures in terms of hurricane losses.

The relativities in Table 3-5 should be used for these buildings. In general, the reinforced concrete roof deck performs about 5-25% better (depending on roof covering type) that the best wood frame house in the main loss relativity tables. Note that a house with a reinforced concrete roof deck receives no further secondary adjustments from this report.

3.3.4 Opening Coverage

Opening protection in Tables 3-2 and 3-3 was limited to protection of glazed openings. Analysis of the additional reduction in loss for protection of non-glazed openings such as doors and garage doors has been made for the houses in Table 3-5. The losses reduce further up to about 5%, depending on the house and location. An average reduction is about 2%.

Therefore, if all openings are protected, then find the appropriate relativity in Tables 3-2 or 3-3, and adjust R by

$$R' = 0.98(R) \ . \quad (3\text{-}4)$$

This adjustment provides for the additional reduction in losses for protection of non-glazed openings.

3.3.5 Unbraced Gable-End

For the "other" roof shape in Tables 3-2 and 3-3, the results are for braced gable ends. Analysis of bottom-chord gable end failures indicates increases in losses of 1-4%.

An average increase in the relativity of about 2% is typical for unbraced gables, and hence,

$$R' = 1.02R \ . \quad (3\text{-}5)$$

Table 3-5. Loss Relativities – Reinforced Concrete Roof Deck[1]

Opening Protection Level	Terrain B - 2% Deductible	Terrain C - 2% Deductible
None	0.44	0.32
Basic	0.38	0.20
Hurricane	0.36	0.18

[1] Integral with reinforced masonry wall; no further adjustments to these relativities.

Hence, the house is rated as "Other" roof shape and the appropriate relativity from Table 3-2 or 3-3 is adjusted by Eqn. 3-5.

3.3.6 Foundation Failures

The results in Tables 3-2 and 3-3 are for restrained foundations. In evaluating several degrees of anchorage, we found that typical ranges of anchorage for site-built houses was adequate to prevent sliding or overturning failures. The analysis for unrestrained foundations show a complicated and large range of effects on the relativities. For weak houses, the increase in loss costs is less than for strong houses since weak houses will also fail in other modes. Very few site-built houses will have unrestrained foundations, so an adjustment for unrestrained foundations will rarely need to be applied.

The simplest way to apply the unrestrained foundation adjustment is to use an average value. An average adjustment for Terrain B houses is 1.38 and an average adjustment for Terrain C houses is 1.54.

For example, say that House A-G (in Terrain B) rests on concrete blocks with no anchorage. Its relativity of 2.37 is adjusted by

$$R' = 2.37\ (1.38) = 3.27\ . \qquad (3\text{-}6)$$

3.3.7 Summary of Secondary Rating Factors

Table 3-6 summarizes the possible secondary adjustments to the relativities. Multiple adjustments should be applied according to

$$R' = \prod_i K_i\, R_i \qquad (3\text{-}7)$$

where K_i is the adjustment factor given in Table 3-6, and R_i is the relativity from Table 3-2 or 3-3. For example, for House B-G in Terrain B with 2% deductible, the adjusted relativity for dimensional lumber deck and reinforced masonry walls is

$$R' = (0.96)\ (0.95)\ (1.00) = 0.91\ . \qquad (3\text{-}8)$$

For House C-H in Terrain B with 2% deductible, the same adjustment produces

$$R' = (0.96)\ (0.95)\ (0.37) = 0.34\ . \qquad (3\text{-}9)$$

3.4 Discussion of Loss Relativity Results

As expected, there is a wide range of relativities from the weakest to the strongest houses. The multiplicative range are factors of about 6 for Terrain B and 8 for Terrain C. These ranges are not as large as actually exists in a territory because not all variables have been considered separately in the classification, as discussed in Appendix C.

Table 3-6. Adjustments to Loss Relativities

Factor	Reference Cell in Tables 3-2 or Table 3-3	Relativity Adjustment Factor (K_i)
Dimensional Lumber Deck	Deck Attachment C	0.96
Masonry Walls	Any	0.98
Reinforced Masonry Walls	Any	0.95
Reinforced Concrete Roof Deck	None	Use Table 3-5 for Relativities
Opening Coverage – All Openings	Basic or Hurricane	0.98
Unbraced Gable End	Any "Other" Roof Shape	1.02
Foundation Restraint	Any	Terrain B: 1.38 Terrain C: 1.54

The Terrain B range of relativity of about 6 is slightly larger than the corresponding range in the FWUA Class Plan, which has a range of about 5 from the weakest to strongest house, considering both primary and secondary rating variables. The FWUA tables are also based on Terrain B and do not consider FBC-equivalent roof coverings. Therefore, a proper comparison of Table 3-2 to the FWUA class plan should be limited to the upper half of Table 3-2. The range of relativity in the upper half of Table 3-2 is from 0.54 to 2.37, a factor of less than 5. Hence, this range is very close to the FWUA class plan range. In addition, we note that Tables 3-2 and 3-3 include three roof deck attachments with a much stronger deck (Deck C) than considered by the FWUA in their Class Plan. Also, the hurricane strap categories include much stronger straps than was considered in the FWUA Class Plan.

The following paragraphs discuss the differences in loss relativity for some of the key variables.

3.4.1 Normalization

The results in Tables 3-2 and 3-3 have been normalized by the loss coats of a "central" or a "typical" house, which makes the judgment of the reasonableness of the relativities easier. We see that the weakest house in Terrain B has loss costs 2.4 times that of a "central" house. The strongest house has loss costs 0.4 of the central house, reflecting the stronger roof, opening protection, hip roof shape, and SWR. These differences are readily explained by differences in component and connection strength and impact resistance. Some insurers may choose to renormalize the results to the weakest house for purposes of implementation. Renormalization, of course, has no mathematical influence on the computation of rates.

Since the FWUA Class Plan (FWUA Manual of Rates, Rules, and Procedures, July 2000) tables were normalized to the weakest house, however, a word of caution is in order in terms of trying to interpret the reasonableness of the results when the relativities are normalized by the weakest house. Normalizing the results by the weakest house makes judgments of the reasonableness of the relativities difficult. It is like normalizing the strength of the proverbial "brick" house to a "straw" house. The "brick" house appears very strong (very low relativity) when compared to a "straw" house. Hence, in Tables 3-2 and 3-3, the results are normalized by a more "central" house with a more common roof deck attachment and a clip roof-to-wall connection (House B-G in Table 3-4). Note that over 60% of the roof decks in the RCMP inspections qualify for Deck B Attachment, the same as House B-G, the selected "central" house.

3.4.2 Roof Deck and Roof-to-Wall Connections

The effect of improved roof deck attachment can be seen in Fig 3-1, which compares HURLOSS predicted deck attachment failure rates for House A-G to House B-G (see Table 3-4) for the Miami location (see Fig. 2-2). This plot shows the average percent of roof deck that has failed from the negative pressures and resulting pressure (suction) loads on the plywood roof deck. The deck for House A-G is nailed with 6d nails at 6/12 spacing and the deck for House B-G is nailed with 8d nails at 6/12 spacing. We see that if these houses experience winds associated with a maximum reference wind speed (10 m above ground) of 125 mph peak gust winds that House A-G loses on average 24% of its roof deck while House B-G loses on average 4% of its deck. At 150 mph, House A-G loses 85% and House B-G loses about 60% on average.

The other difference in these two houses is the roof to wall connection. House A-G has a toe-nail connection and House B-G has a clip connection. Figure 3-2 plots the percent

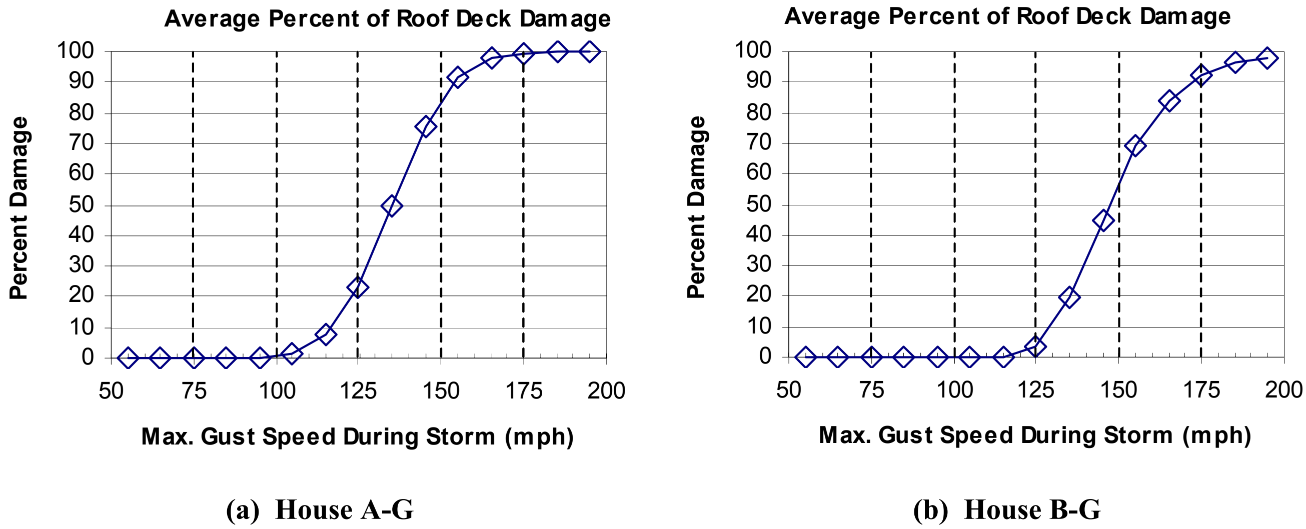


Figure 3-1. Comparison of HURLOSS Estimated Roof Deck Damage for 6d versus 8d Nails for Miami Location

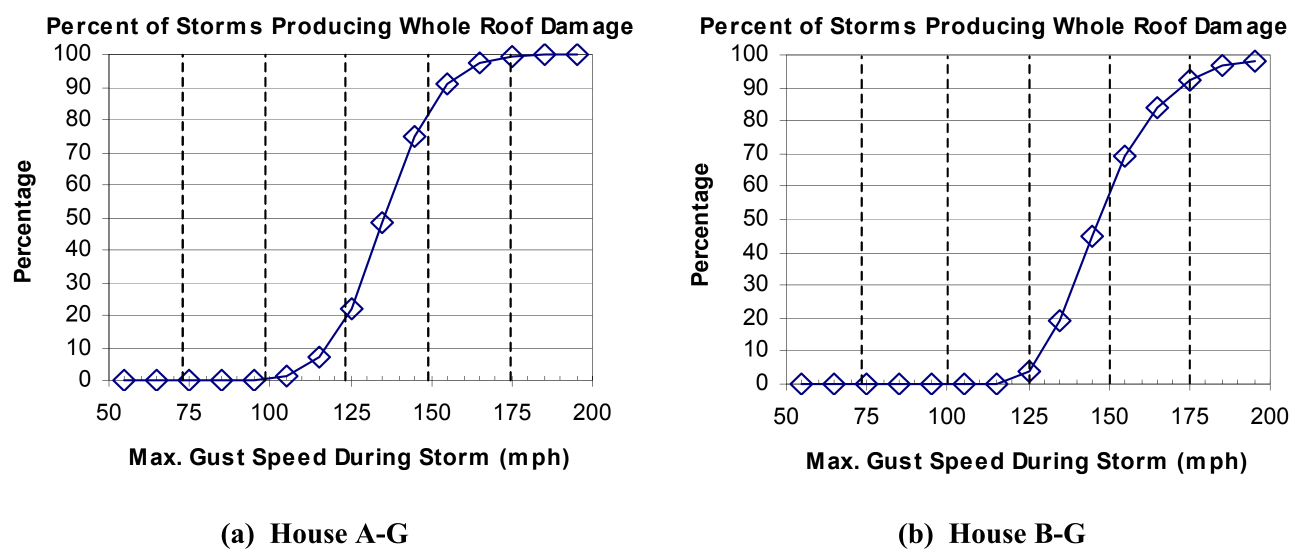


Figure 3-2. Comparison of HURLOSS Estimated Whole Roof Failures for Toe-Nail versus Clip for Miami Location

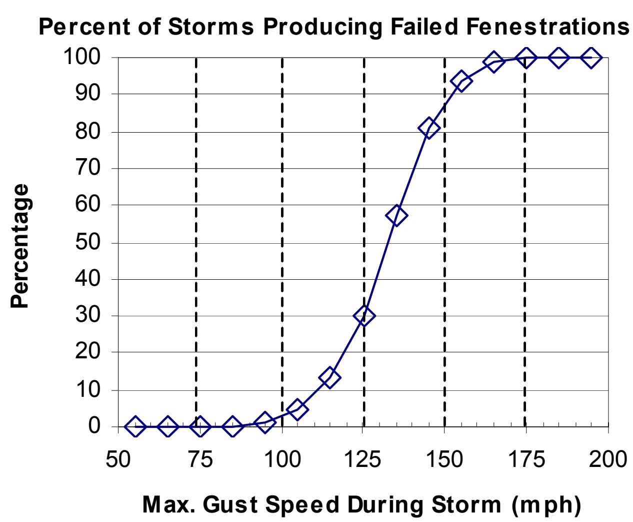
of storms that produce whole roof failures for these same two houses. Whole roof failure occurs when the loads on the roof exceed the uplift resistance of the roof-to-wall connections. The roof, or major portions of it, fail and lift off the house. The difference in strength between toe nails and clips results in a much reduced frequency of whole roof failures. For 125 mph reference peak gust winds, House A-G experiences whole roof type failures in about 20% of the hurricanes whereas House B-G experiences whole roof failures in 3-4% of the storms.

The combination of strengthening these two connections significantly reduces the failure rates of roof deck and whole roof failures. We see from the relativities that House A-G has loss costs (for 2% deductible) that are about twice that of House A-G, reflecting the fact that the roof deck and whole roof failures rates for peak gust wind speeds less than about 150 mph are significantly different.

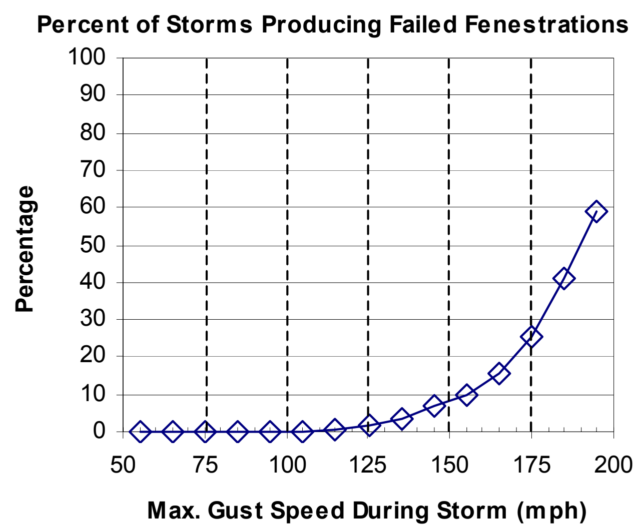
3.4.3 Protection of Openings

Hurricane opening protection refers to impact resistant glass or shutters for all glazed openings. The significant effect of hurricane opening protection can be seen in several ways. First, consider the number of failed openings. Figure 3-3 compares the average number of failed fenestrations for House A-G (or House B-G since both are the same except for the roof deck attachment) to the same house with opening protection. For the unprotected houses, about 30 percent of the storms with 125 mph peak gust winds result in one or more failed fenestrations, whereas only 1-2% of these storms produce one or more failed openings for the protected house. At 150 mph peak gust winds, the difference is just as dramatic: about 95% of the storms result in failed openings for the unprotected house whereas only 8% of such storms produce failures for the protected house.

A second result from the protection of openings is a reduction in the number of whole roof failures. To see this effect, we need to compare two identical houses with the only difference being the protection of openings. For this comparison we use House A-G (located at Lighthouse Point) compared to itself with the only difference being hurricane protection on the building. Figure 3-4 shows the difference in whole roof failures experienced by the two buildings. At 150 mph peak gust winds the house with hurricane protection of openings experiences about ½ the whole roof failure rate (25%) versus the house with no opening protection (50% failure rate). The same comparison for a slightly stronger building, House B-G is shown in Fig. 3-5. We see the same effect except the relative difference in whole roof failures is somewhat less for the stronger house. This is why the relativities are all nonlinear across weak to strong buildings. Since the stronger building has a better roof-to-wall connection, it is less vulnerable to whole roof failures and the relative improvement for

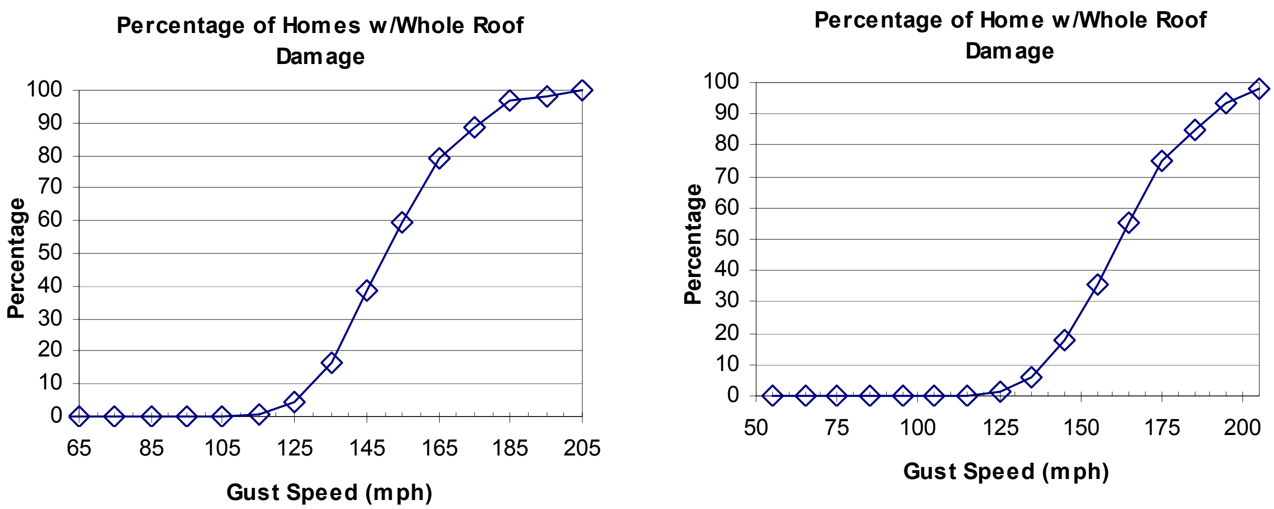


(a) House A-G (No Opening Protection)



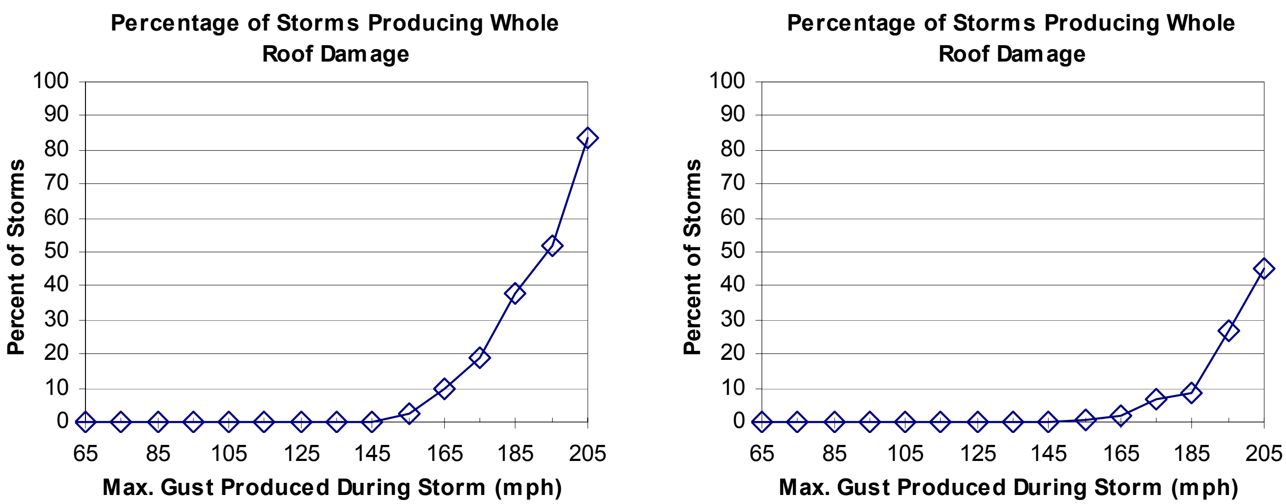
(b) Same House with Opening Protection

Figure 3-3. Comparison of HURLOSS Estimated Fenestration Failures for No Opening Protection versus Opening Protection for Miami Location



(a) No Opening Protection **(b) Opening Protection**

Figure 3-4. Comparison of HURLOSS Estimated Whole Roof Failures for House A-G at Lighthouse Point



(a) No Opening Protection **(b) Opening Protection**

Figure 3-5. Comparison of HURLOSS Estimated Whole Roof Failures for House B-G at Lighthouse Point

opening protection is less than that for the weaker building. Hence, the relativity effect of opening protection for A-G (2% deductible in Terrain B) is a 44% reduction in loss costs (2.37 to 1.33) whereas the effect of opening protection for B-G in Terrain B is a 20% reduction in loss costs relativity (1.0 to 0.80).

The difference in relativity for the two houses shows a bigger percent reduction for the weaker house. Opening protection serves two purposes: (1) it helps to keep the roof on by reducing the chance of internal pressurization of the building; and (2) it keeps water and wind from penetrating the openings and damaging the interior of the house.

3.4.4 Hip-Shaped Roof

The effect of roof shape can be illustrated by comparing roof cover failures, roof deck failures and whole roof failures for hip versus gable houses. Figures 3-6 shows these comparisons for gable and hip with Deck B, toe-nails, and no opening protection.

The failure rates for each of these components are much less for the hip shaped roof, reflecting the improved aerodynamics and the fact that the hip has roof-to-wall connections on 4 sides versus 2 sides for the gable. Hence, there is a sizable relativity difference for the effect of roof shape. This difference is also highly nonlinear, being much more for weaker houses than for stronger houses. The relative difference is about 2 for very weak houses and about 1.15 for strong houses in Terrain B.

3.4.5 Wood Frame versus Masonry Walls

Figure 3-7 shows the frequency of wall failures for frame versus reinforced masonry walls for the same house (House B-H). While there clearly are more wall failures for the wood frame walls, reflecting the weaker lateral strength of these walls compared to masonry, we also see that the wall failure rate is much less than the roof deck, openings, and whole roof failure rates. Hence, although reinforced masonry walls are stronger, the effect of wall construction is a secondary effect. This can be visualized also from some of the figures in Section 1. Figure 1-4 shows wood framed walls that are largely intact but the roof decks and openings have failed. These houses are all near 100% loss because of the interior water damage and so the wall performance is of secondary importance.

Another example is Fig 1-6, a masonry walled house. While the walls are still standing, the house is also near a 100% loss due to roof deck failure, opening failure, and gable end failure. The National Association of Home Builders (NAHB) post Andrew survey also shows many buildings with standing walls, but numerous opening and roof failures, which control the losses to the building. Hence, the relativity adjustment for wall construction is small because the other building components generally always fail first.

3.4.6 Hur Reports

HURLOSS produces an output file for each house that can be used to generate a physical damage and insurance loss report (Hur Report). Hur Report examples, edited to delete loss costs and other insurance information not appropriate for this report, are provided in Appendix D. These outputs indicate how the failure rates of various components change as the house is made stronger. Some of the plots in the previous paragraphs have been extracted from these reports.

3.5 Treatment of Deductibles

The loss relativities in Tables 3-2, 3-3, 3-5, and 3-6 are based on loss costs corresponding to 2% deductibles. Other deductibles affect the relativities in different ways, depending on the strength of the house. In general, the loss costs for stronger houses (small relativities) are more sensitive to deductible since the damage to these houses is often exterior and roof covering damage. Going from, say $500 deductible to 5% deductible for strong buildings makes a huge difference in the loss costs since 5% deductible may largely pay for exterior losses, like painting, etc. The situation is opposite for weak houses, which have large relativities. Loss costs are less sensitive to deductible for weak houses since the house envelope is more easily breached and the subsequent water damage and contents losses are so large that deductible has a smaller impact on reducing loss costs.

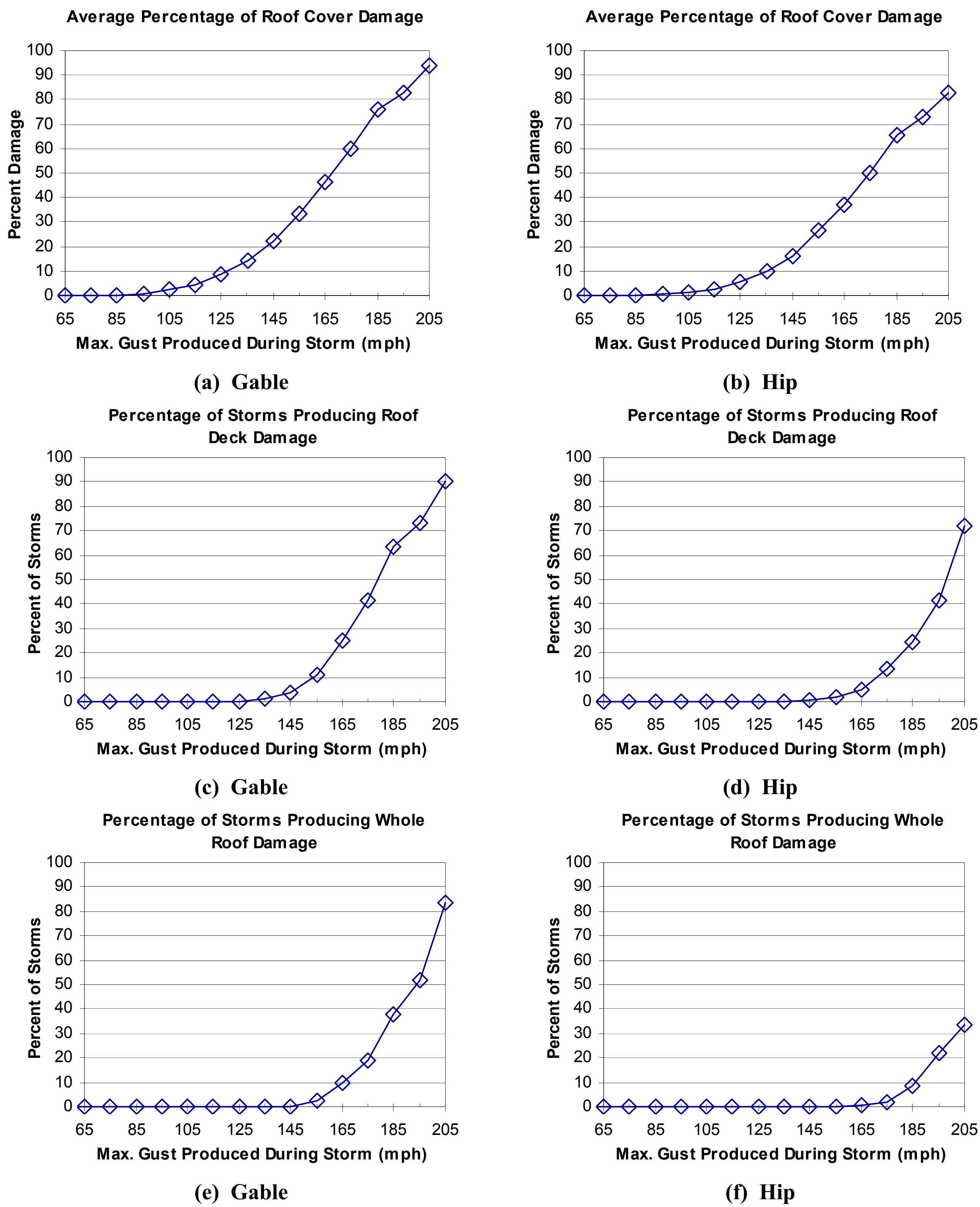
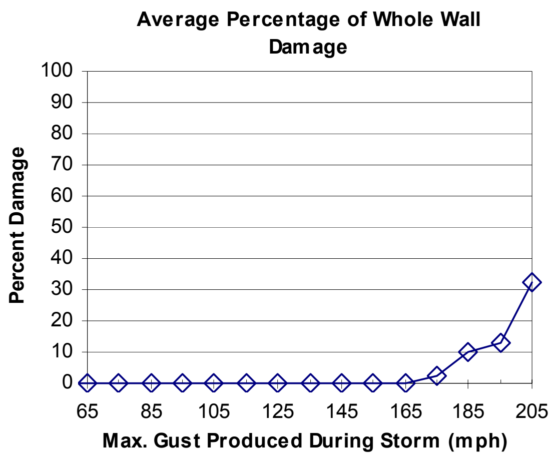
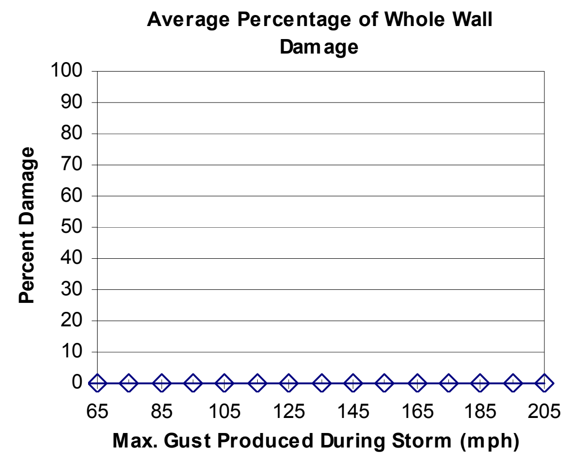


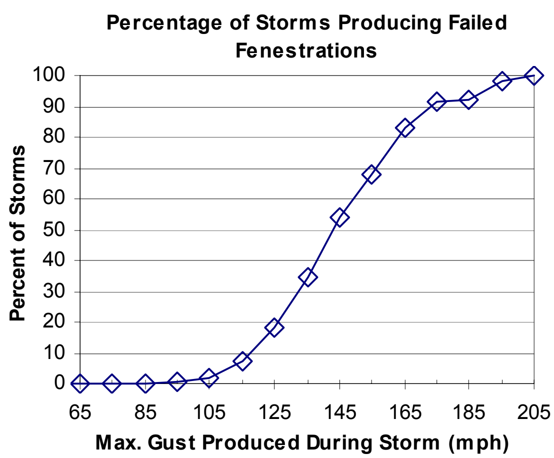
Figure 3-6. Comparison of HURLOSS Estimated Failures for Gable (House A-G) versus Hip (House A-H) at Lighthouse Point



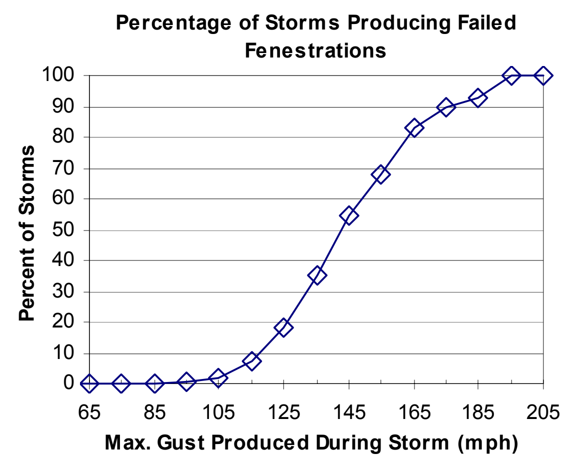
(a) Wood Frame



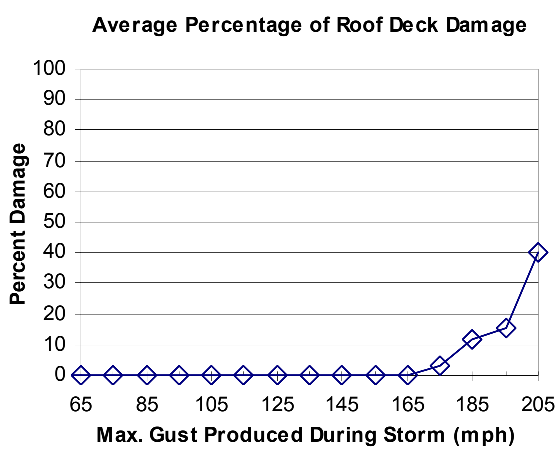
(b) Reinforced Masonry



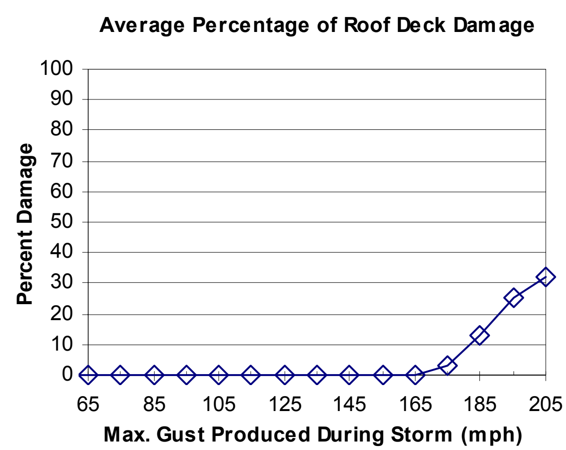
(c) Wood Frame



(d) Reinforced Masonry



(e) Wood Frame



(f) Reinforced Masonry

Figure 3-7. Comparison of HURLOSS Estimated Failures for Wood Frame and Masonry Walls (House B-H) at Lighthouse Point

There are many options, ranging from simple approximations to more exact calculations, to adjust these relativities to reflect deductibles other than 2%. To illustrate one approach, we have analyzed each modeled house for all of the locations in Table 2-2.

HURLOSS Computed Deductible Adjustment. Every house in the calculational matrix was analyzed for 0, 2, and 5% deductibles. The results indicate deductible dependencies on both location and house strength. For example, Fig. 3-8 illustrates the ratios of the relativities for 0% and 5% deductibles compared to the relativity for 2% deductible for Location 30. The horizontal axis is the natural logarithm of the Relativity, $R_{2\%}$, and the vertical axis is the multiplier needed to adjust to 0% or 5% (see legend in figure). The top part of Fig. 3-8 shows the relativity adjustment to go from 2% to 0%. The mean of the 288 points (representing each combination of wind resistive features per Table 3-3) is 1.17. The bottom half of Fig. 3-8 plots the 288 points for the 2% to 5% deductible adjustment. The mean adjustment is 0.86.

Figure 3-8 shows significant variation that depends on $R_{2\%}$. Note the separation of the points into two clusters for each plot. This separation is FBC roof cover versus non-equivalent FBC roof covers. For locations in reduced wind speed regions, these types of plots show further separation of the data and one can see the effects of roof shape and other variables. Obviously, a more detailed analysis of this data is needed to provide the best possible representation of relativity dependence on deductible.

For purposes of this report, we present several simple options. The first is simply a computation of the mean deductible adjustment for each location. These mean adjustments take into account location dependence and are the average adjustment for all 288 houses per Tables 3-2 and 3-3. These results are shown in the initial columns of each part of Table 3-7.

For the second option, we have fitted the data at each location to a polynomial of the form

$$D_{2\%\ to\ x\%} = A \cdot [\ln(R'_{2\%})]^2 + B \cdot \ln(R'_{2\%}) + C \qquad (3\text{-}10)$$

where A, B, and C are the parameters of the fit determined by a least squares approach. Plots of Eqn. 3-10 for Location 30 are illustrated in Fig. 3-8.

Table 3-7 summarizes the results of this fitting process. The r^2 values for each fit are also shown to give the user an idea of the goodness of fit. The r^2 values are reasonably good for Terrain C locations and most of the Terrain B locations. For the lower wind speed regions, there is much more dependence on the specific house features, and these simple one variable fits do not capture the variance very well. Nevertheless, this approach provides more accurate deductible adjustments than simply using the mean values.

In using Eqn. 3-10, the effective range for Terrain B is $0.40 \leq R'_{2\%} \leq 2.30$ and the effective range for Terrain C is $0.20 \leq R'_{2\%} \leq 1.55$. If $R'_{2\%}$ is larger than the upper bound (or smaller than the lower bound), the value corresponding to the upper bound (or lower bound) should be used for the adjustment factor.

A third option to further simplify the deductible adjustment is to average the adjustment over multiple point locations (wind speed zones). Table 3-8 presents these mean value results over the wind speed ranges for each terrain.

A fourth option is to fit the data from multiple locations over the wind speed ranges. Table 3-8 gives the A, B, C parameters and r^2

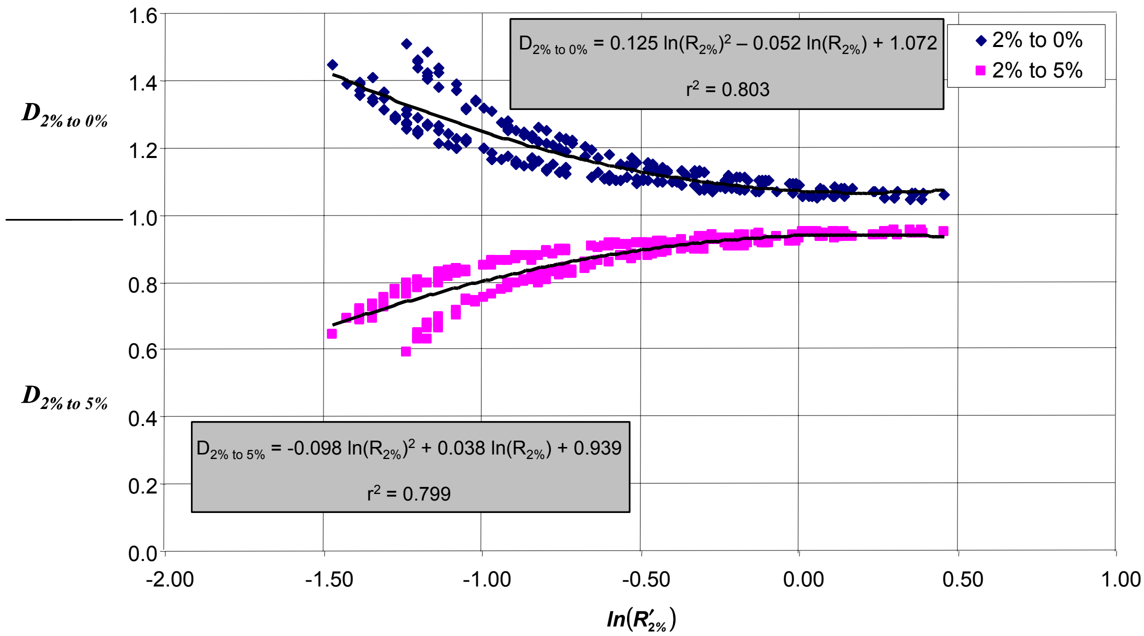


Figure 3-8. Relativity Adjustments for 0% and 5% Deductible for Terrain C Location 30 (Miami)

values. As expected, the r^2 values are lower since the fitting occurs over multiple locations.

An alternative to this statistical fitting process is a set of 62 (31 locations by 2 adjustments) tables that give the deductible adjustment cell by cell in Tables 3-2 and 3-3.

Example Deductible Computation. The determination of the relativity for a house is achieved by multiplying the final adjusted relativity (R') by the deductible adjustments in Table 3-7 or 3-8. That is,

$$R'_{x\%} = \frac{LC_{x\%}}{LC_{Base_{2\%}}} = R'_{2\%}\, D_{2\% \text{ to } x\%} \qquad (3\text{-}11)$$

where LC denotes loss costs and $R'_{2\%}$ is the relativity from Tables 3-2 or 3-3, adjusted as needed by the secondary factors.

For example, consider House B-H in Terrain B, in Royal Palm Beach, $R'_{2\%}$ = 0.76. To compute R' for 0% deductible, we have the following options, as discussed previously:

1. *Location Mean.* The mean adjustment for this location is $\overline{D}_{2\% \, to \, 0\%}$ = 1.31 from Table 3-7. Hence,

   $$R'_{0\%} = 1.31\ (0.76) = 1.00\ .$$

2. *Location Polynomial.* Using the polynomial equation for Terrain B Location 21 with A = 0, B = -0.243, and C = 1.244 from Table 3-7, we use Eqn. 3-10 to compute $D_{2\% \, to \, 0\%}$ = 1.31, which, coincidentially, equals the mean adjustment. Hence,

   $$R'_{0\%} = 1.31\ (0.76) = 1.00\ .$$

3. *Wind Speed Region Mean.* From Table 2-2, we see that Royal Palm Beach corresponds to the 140 mph wind region. Hence, we use the V > 130 parameters from Table 3-8. The mean adjustment is 1.29 and, hence,

   $$R'_{0\%} = 1.29\ (0.76) = 0.98\ .$$

Table 3-7. HURLOSS Deductible Multiplier Adjustment (D) by Location

Terrain B Location	$D_{2\%\ to\ 0\%}$					$D_{2\%\ to\ 5\%}$				
	Mean	A[1]	B[1]	C[1]	r^2	Mean	A[1]	B[1]	C[1]	r^2
1	2.74	-	-0.674	2.549	0.279	0.49	-	0.227	0.557	0.526
2	2.58	-	-0.687	2.388	0.375	0.49	-	0.237	0.558	0.570
3	1.77	-	-0.429	1.650	0.395	0.64	-	0.227	0.708	0.641
4	1.90	-	-0.469	1.770	0.387	0.60	-	0.238	0.672	0.660
5	1.96	-	-0.495	1.820	0.442	0.57	-	0.244	0.644	0.679
6	1.67	-	-0.406	1.551	0.434	0.67	-	0.221	0.734	0.638
7	1.66	-	-0.415	1.546	0.542	0.64	-	0.241	0.709	0.712
8	1.55	-	-0.358	1.451	0.415	0.71	-	0.217	0.772	0.652
9	1.59	-	-0.381	1.481	0.466	0.69	-	0.219	0.752	0.640
10	1.48	-	-0.337	1.383	0.550	0.71	-	0.222	0.770	0.706
11	1.57	-	-0.353	1.471	0.408	0.71	-	0.204	0.763	0.617
15	1.43	-	-0.309	1.345	0.500	0.74	-	0.205	0.794	0.656
16	1.43	-	-0.310	1.344	0.561	0.72	-	0.217	0.781	0.722
17	1.35	-	-0.272	1.277	0.548	0.76	-	0.200	0.815	0.692
21	1.31	-	-0.243	1.244	0.538	0.78	-	0.187	0.832	0.682
24	1.28	0.022	-0.213	1.210	0.523	0.80	-0.055	0.157	0.856	0.668
25	1.28	0.018	-0.214	1.211	0.522	0.80	-0.055	0.157	0.856	0.675
Terrain C Location	$D_{2\%\ to\ 0\%}$					$D_{2\%\ to\ 5\%}$				
	Mean	A[1]	B[1]	C[1]	r^2	Mean	A[1]	B[1]	C[1]	r^2
12	1.56	0.247	-0.302	1.244	0.846	0.71	-0.103	0.155	0.861	0.778
13	1.69	0.272	-0.385	1.308	0.870	0.68	-0.088	0.186	0.835	0.759
14	1.49	0.249	-0.247	1.203	0.844	0.73	-0.119	0.133	0.878	0.780
18	1.42	0.236	-0.199	1.171	0.869	0.75	-0.120	0.123	0.886	0.807
19	1.34	0.202	-0.149	1.143	0.840	0.78	-0.113	0.094	0.901	0.793
20	1.33	0.196	-0.136	1.136	0.833	0.79	-0.114	0.086	0.904	0.793
22	1.32	0.196	-0.131	1.128	0.849	0.79	-0.115	0.088	0.906	0.795
23	1.30	0.187	-0.121	1.125	0.836	0.80	-0.112	0.080	0.909	0.795
26	1.21	0.145	-0.071	1.087	0.819	0.84	-0.103	0.051	0.930	0.794
27	1.16	0.105	-0.049	1.070	0.780	0.87	-0.082	0.036	0.941	0.774
28	1.19	0.138	-0.062	1.079	0.818	0.85	-0.104	0.045	0.935	0.807
29	1.27	0.189	-0.101	1.102	0.862	0.80	-0.131	0.073	0.919	0.846
30	1.17	0.125	-0.052	1.072	0.803	0.86	-0.098	0.038	0.939	0.799
31	1.23	0.164	-0.077	1.088	0.840	0.83	-0.119	0.056	0.928	0.826

[1] For use with Eqn. 3-10.

4. *Wind Seed Region Polynomial.* From Table 3-8, A = 0.015, B = -0.223, and C = 1.221. We compute

$$R'_{0\%} = 1.28\ (0.76) = 0.97\ .$$

For this example, these options all give similar answers, but that will not always be the case. These are approximations and clearly the fact that the loss relativity adjustment for deductible depends on both location and house features makes it difficult to simplify the adjustment with extremely high accuracy.

Interpolation. For deductibles other than 0, 2, and 5%, interpolation can be used to estimate the adjustment to the loss relativity.

Table 3-8. Simplified Relativity Deductible Adjustment Approach by Wind Region

FBC Wind Speed Zones (mph)	Terrain B	$D_{2\% \text{ to } 0\%}$					$D_{2\% \text{ to } 5\%}$				
		Mean	A[1]	B[1]	C[1]	r^2	Mean	A[1]	B[1]	C[1]	r^2
V ≤ 110	1 -6	2.10	-	-0.526	1.955	0.135	0.58	-	0.232	0.645	0.437
110 < V ≤ 130	7 - 11, 15-17	1.51	-	-0.342	1.412	0.376	0.71	-	0.216	0.769	0.605
V > 130	21, 24, 25	1.29	0.015	-0.223	1.221	0.515	0.79	-0.053	0.162	0.850	0.668
FBC Wind Speed Zones (mph)	Terrain C	$D_{2\% \text{ to } 0\%}$					$D_{2\% \text{ to } 5\%}$				
		Mean	A[1]	B[1]	C[1]	r^2	Mean	A[1]	B[1]	C[1]	r^2
110 < V ≤ 130	12-14, 18-20	1.47	0.234	-0.236	1.201	0.660	0.74	-0.110	0.129	0.878	0.718
V > 130	22,23,26-31	1.23	0.156	-0.083	1.094	0.683	0.83	-0.108	0.058	0.926	0.719

[1] For use with Eqn. 3-10.

Linear interpolation is reasonably accurate over small ranges. For example, if the same house has a $500 deductible on $100,000 Coverage A limit, the equivalent percent deductible is 0.5%. The relativity is computed by linear interpolation, or

$$R'_{0.5\%} = 0.98 - \left(\frac{0.5\%}{2.0\%}\right)(0.98 - 0.76) = 0.93 \quad (3\text{-}11)$$

where 0.98 is the computed relativity for 0% deductible (using Option 3 above corresponding to the mean values in Table 3-8) and 0.76 is the relativity for 2% deductible from Table 3-2.

These computations are readily programmed and provide an approximate method to treat fixed amount deductibles and percentages other than 2%.

Comparison to Florida Hurricane Commission Submittals. A check on the reasonableness of these deductible adjustments has been made by reviewing the modeler submissions to the 2000 Standards of the Florida Commission on Hurricane Loss Projection Methodology. The results for two counties, Alachua (a low wind speed location) and Miami-Dade (a high wind speed location) are shown in Table 3-9. They were computed by using each modeler's weighted average loss costs for 0, 2 and 5% deductible. While there is notable variation across modelers, the deductible adjustments are similar to those in Table 3-9 and indicate larger adjustments for locations in lower wind speed regions.

3.6 Statistical Convergence of Loss Costs and Statistical Error in Loss Relativities

The hit and miss nature of hurricanes and the fact that loss costs are driven by intense storms means that the estimation of hurricane loss costs requires a large number of simulated years. Further, the modeling of single variable (in some cases) differences in construction features requires high convergence of loss costs in order to reasonably estimate the relativities.

Error in Loss Costs. Figure 3-9 illustrates the convergence of average annual loss (AAL) for Wood Frame House 0011G in Terrain B with the construction features of House B-G in Table 3-4. The plot is normalized so that the 300,000 year computed AAL is shown as unity. The standard error $\left(\sigma/\sqrt{N}\right)$ in the estimated mean (AAL) for the 300,000-year simulation for this case is 1.55%. This means that the 95% confidence bounds on the computed loss costs for the base class house is about ± 3%. This error represents the error in estimating the base class loss costs for a perfect model. Uncertainties in the model are not included in this analysis of loss cost convergence.

Table 3-9. Example Deductible Adjustments Computed from FHCLPM Submittals

County	Modeler	From 2% to 0%	From 2% to 5%
Alachua (V ≤ 110)	EWB	2.48	0.48
	AIR	1.40	0.83
	RMS	1.43	0.69
	EQE	2.30	0.47
	ARA	1.54	0.51
Miami-Dade (V > 130)	EWB	1.43	0.70
	AIR	1.23	0.82
	RMS	1.27	0.77
	EQE	1.22	0.82
	ARA	1.09	0.89

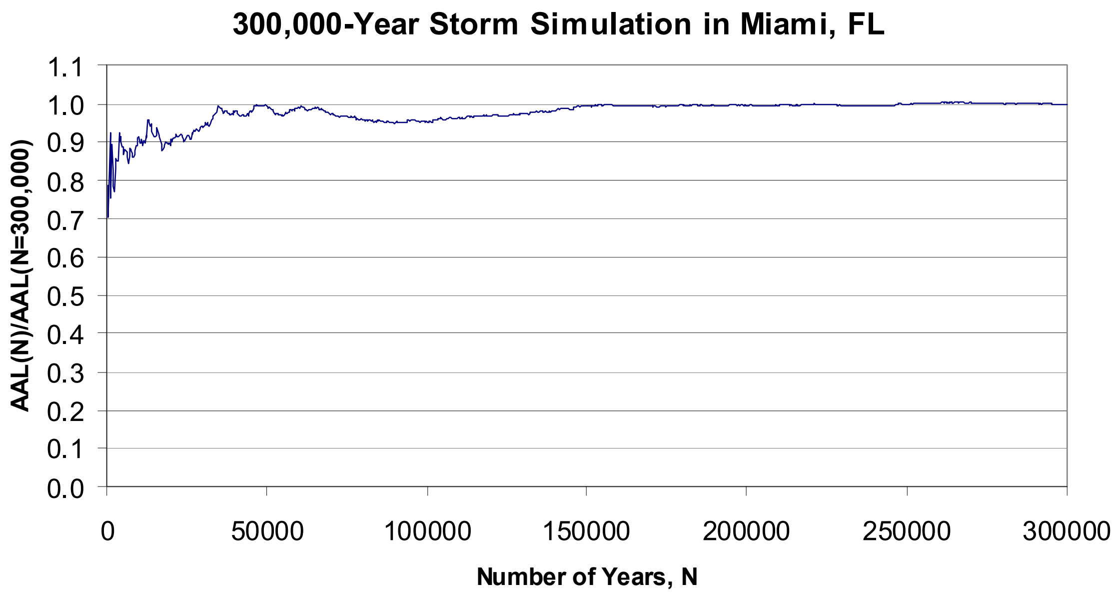


Figure 3-9. Example Statistical Convergence of Normalized Average Annual Loss for Typical House in Miami

Error in Loss Relativities. The user should be aware that the error in the loss relativities is not the same as the above illustrated statistical error in a base class loss costs estimation for a 300,000 year simulation. The statistical error in the loss relativities (ratio of two correlated means) is less. This error in the loss relativities also depends on how far removed the house is from the base class (typical) house. The statistical error in the typical house relativity is zero (all of its statistical error is the error in the base class loss costs computation, which is about 1.5%, as noted above).

To illustrate the magnitude of the errors in the loss relativity in Tables 3-2 and 3-3, the statistical error in the loss relativity for two example houses has been computed numerically. The loss relativity R is

$$R = \frac{(AAL)_{House\ X}}{(AAL)_{Typical\ House}} = \frac{L_x}{L_t} \qquad (3\text{-}12)$$

where *AAL* is the expected value of loss in one year. The loss relativity *R* is the ratio of two expected values and the variance of *R* can be estimated by

$$\sigma^2(R) \approx \left(\frac{\mu_{L_x}}{\mu_{L_t}}\right)^2 \left[\frac{\sigma^2(L_x)}{\mu_{L_x}^2} + \frac{\sigma^2(L_t)}{\mu_{L_t}^2} - \frac{2\,cov(L_x, L_t)}{\mu_{L_x}\,\mu_{L_t}}\right]. \tag{3-13}$$

Performing these calculations for Houses A-G (weak); B-G (typical); and C-G (strong) in Table 3-4 for a Miami location yields estimate of the normalized standard error of 0.67% for the weak house relativity and 0.64% for the strong house relativity. From this analysis, we can conclude that the error in the loss relativities in Tables 3-2 and 3-3 are less than about 1%. These loss relativity errors are less than the statistical error in the estimation of the base class loss costs for a 300,000 year simulation.

Again, this discussion of statistical errors assumes that the model is perfect. The uncertainties resulting from imperfect models is generally much larger than the statistical error when a very large number of years is simulated.

4.0 LOSS RELATIVITIES FOR CONSTRUCTION TO FBC 2001

4.1 General

The FBC 2001 will have a notable impact on new construction in the state of Florida. The code will improve the design and construction of new buildings with regard to wind loads, particularly in the windborne debris regions. Prior to the FBC 2001, only a few counties in the state required consideration of windborne debris. As indicated in Section 2, the FBC 2001 does allow prescriptive methods of construction to be used, but these are limited largely to Terrain B exposure. In general, the FBC 2001 will result in more involvement of design professionals in residential construction.

The development of the loss relativities for new construction requires consideration of two ASCE 7-98 design options in the wind-borne debris zone; design as an enclosed building or design as a partially-enclosed building. Section 4.2 presents a summary of the major design issues of the Florida Building Code. Appendix E provides a more in-depth discussion and also presents the analysis of the loss relativities for new construction to the FBC 2001. Appendix F presents an example of the design calculations that were performed by ARA in order to model the critical wind resistive features of houses built to the new code. Section 4.3 presents the loss relativity tables for new construction and Section 4.4 presents a brief discussion of rating verification issues for new construction.

4.2 Effect of the Florida Building Code on New Construction

With respect to the rating of buildings for insurance purposes, the FBC makes the following changes to construction techniques in the state.

1. The introduction of a Wind-Borne Debris zone (WBDZ) means that new homes in this region must now either have impact resistance protection on all glazed openings *or* be designed for higher wind pressures than previously. This change means that a designer must now choose between designing the structure as either an enclosed or partially enclosed building.
2. A designer will now consider only 60% of the dead load in resisting uplift loads in the FBC, which means that roof-wall straps will be stronger than they were using the SBC.
3. A new wind speed map and new terrain exposure categories means that buildings in some parts of the state will be designed for higher wind pressures than they were previously under the SBC. This change will affect the design of several parts of the structure including the strength of the windows, the strength of the roof deck and its connections, the wall design, and the foundations.
4. More wind resistant roof coverings will now become the standard roof covering in most of the state. For design wind speeds of 110 mph and greater, the asphalt shingles must be tested according to ASTM D 3161 (modified to 110-mph) or Miami-Dade PA 107.
5. Structures requiring design wind speeds of 120 mph and higher cannot necessarily be built using prescriptive design documents unless the wind loads on which the prescriptive documents are based satisfy the provisions of the FBC. Hence, there will be more involvement of design professionals for construction in higher wind speed areas.

4.2.1 Design Scenario in Wind-Borne Debris Region (WBDR)

An "Enclosed" structure is designed assuming that all the openings are closed and therefore the wind loads are determined using a small internal pressure inside the building. Alternatively, a "Partially Enclosed" building is designed assuming that one or more areas on the building are open to allow the wind to enter the building and pressurize the interior. This pressurization means that individual parts of the building, such as the windows, doors, trusses, and roof decking must be designed to be stronger than the same features in an "Enclosed" house.

For insurance rating purposes, the distinction between the enclosed and partially-enclosed designs in the WBDR with respect to loss costs is largely determined by the presence or absence of opening protection on all glazed openings[1]. Enclosed designs in the WBDR will perform better than partially-enclosed designs and will have lower losses because of the effect of the opening protection. Section 3.4.3 discusses the significance of opening protection in reducing damage and loss.

Examination of the results in Appendix E indicates that the partially-enclosed designs are only marginally better than an equivalent enclosed design without shutters. The small increase in performance is due to the larger strap size, tighter roof deck nailing pattern, and stronger windows and doors.

[1] In the HVHZ, all openings must be protected (see Section 1626 of FBC 2001).

4.2.2 Definition of Terrain "Exposure Category"[2]

The FBC has adopted a different definition of Exposure C than appears in the text of ASCE 7-98. Exposure C, (known as the open country exposure) in the FBC is defined as Broward and Miami-Dade counties (HVHZ), barrier islands within 5000 ft of the high water line, and 1500 ft from the coastline in the rest of the state. All other buildings will be designed for Exposure B regardless of whether the structure is in the middle of a field or in the middle of a suburb. Hence, the loss relativities for new construction are computed separately for terrain Exposures B and C since the design loads are dependent on terrain.

4.3 Loss Cost Relativity Tables

For each of the 31 locations, the roof deck nailing pattern, the roof-to-wall connection, and the window design pressures on the three study homes were designed to the minimum requirements of the Florida Building Code as described above. These "designed" homes were analyzed with HURLOSS to estimate the loss cost of each of the homes at each location. Over one hundred FBC 2001 house designs were produced, reflecting the different design wind speeds, treatment of internal pressure, house geometry and roof shape, and wall construction. Over 8,000 HURLOSS computations were performed for these FBC houses at different locations in Florida.

The average of the loss costs for the base class (typical) houses in the existing building study were calculated for each location, and used to determine the relativity of

[2] ASCE-7 uses the term "Exposure" to define the earth's surface roughness for purposes of grouping this roughness into several distant categories for wind load estimation. Insurers need to be aware of this use of the term "Exposure" when reading building code and wind engineering literature.

each "designed" home. That is, we normalized the new construction relativities by the same values in the existing building study so that the relativity tables would be consistent with each other.

The analysis summarized in Appendix E shows that for classification purposes for hurricanes, the key variables for new construction are:

- Terrain Exposure Category
- Roof Shape
- Opening Protection
- Design Wind Speed.

Appendix E contains a more detailed explanation of how these factors affect the strength of various features of the house. It also discusses several other definitions from the FBC that affect the overall strength of the house.

Table 4-1 presents the relativity results for new construction for 2% deductible. The top part of the table covers all new construction that does not have a reinforced concrete roof deck. This applies to well over 99% of new construction. The lower portion applies only to those houses with a reinforced concrete roof deck built to ACI 318 and tied integrally to reinforced masonry walls.

Our analysis of the results indicates that the variation in relativities between wind speeds is notable for the lower wind speed levels (100 and 110 mph) and that the higher wind speeds can be grouped into ≥ 120 mph. Therefore, Table 4-1 shows only three wind speeds: 100 mph, 110 mph, and ≥ 120 mph.

Our analysis also indicates that there was a small difference in relativity between an enclosed design without opening protection and a partially enclosed design (also without opening protection). To recognize the contribution to the overall strength of the roof and windows made by the partially-enclosed assumption, a small reduction has been built into the values of Table 4-1 as appropriate.

We note that Opening Protection in Terrain Exposure B and Exposure C means that all glazed openings (i.e., those with glass or plastic) are protected with impact rated glazing or shutters. The requirements for the High Velocity Hurricane Zone (HVHZ) are slightly different in that all openings including doors and garage doors must be protected with shutters or impact resistant products. The results of our simulations of houses in the HVHZ include this additional protection requirement for the HVHZ in Table 4-1.

The analysis for opening protection for new construction was performed only for devices that meet the impact and pressure cycling test standards. Although wood structural panels (plywood) are allowed by the FBC (except in the HVHZ), modeling and analysis of that option was not performed in this study.

Interpolation for deductibles other than 2%, such as fixed dollar deductibles or other percentages, is described in Section 3.5. The deductible adjustment is applied to the final relativity.

4.3.1 Additional Adjustments

The application of the correction factors from the sensitivity studies in Section 3.3 also apply in general to new construction, as follows:

- The dimensional lumber roof deck credit is designed for older homes constructed before plywood was commonly used in housing markets. However, if a new house does have a dimensional lumber roof, this credit is still applicable.

Table 4-1. Loss Relativities for Minimum Design Construction to FBC 2001 (2% Deductible)

FBC 2001 Construction					Other Roof Shape		Hip Roof Shape	
Roof Deck	Terrain Exposure[2]	FBC Wind Speed[11] (mph)	Internal Pressure Design[3]	WBDR[4]	No Opening Protection	Opening Protection	No Opening Protection	Opening Protection
Other Roof Deck[9]	B	100	Enclosed	No	0.76	-[5]	0.51	-[5]
		110	Enclosed	No	0.66	-[5]	0.51	-[5]
		≥ 120	Enclosed	No	0.61[6]	-	0.52[6]	-
				Yes	-	0.48	-	0.41
			Part. Enclosed	Yes	0.60	-[7]	0.51	-[7]
	C	≥ 120	Enclosed	Yes	-	0.27	-	0.23
			Part. Enclosed	Yes	0.37	-[7]	0.30	-[7]
	HVHZ		Enclosed	Yes	-[8]	0.26	-[8]	0.23
Reinforced Concrete Roof Deck[10]	B	Any	Enclosed	No	0.44	-[5]	0.44	-[5]
				Yes	-	0.36	-	0.36
			Part. Enclosed	Yes	0.43	-[7]	0.43	-[7]
	C	Any	Enclosed	Yes	-	0.18	-	0.18
			Part. Enclosed	Yes	0.31	-[7]	0.31	-[7]
	HVHZ		Enclosed	Yes	-[8]	0.17	-[8]	0.17

[1] Table is for houses built to Minimum Wind Loads of FBC 2001. Houses built to higher loads should use this table and the adjustments in Table 4-2.
[2] See Figure 6.1 and FBC 1606.1.8.
[3] FBC 1606.1.4.
[4] WBDR = Wind-Borne Debris Region (FBC 1606.1.5 and Section 2.2.1 of this report).
[5] Not applicable to Minimum Load Design in non-WBDR.
[6] This relativity applies to non-WBDR locations.
[7] Not applicable to Minimum Load Design for Partially Enclosed Buildings in WBDR.
[8] HVHZ requires WBD Opening Protection.
[9] Secondary Rating Factors: applicable to "Other Roof Decks"
i. Dimensional lumber roof deck: K = 0.96
ii. Reinforced masonry walls: K = 0.95
iii. All openings protected in non-HVHZ: K = 0.98
iv. These factors are applied per Eqn. 3-7.
[10] No secondary rating factor adjustments to these relativities.
[11] FBC wind speed corresponding to house location.

- Wall construction – The results in Table 4-1 are for wood frame houses. New masonry houses may use the same adjustment factor as for existing construction.
- Additional Opening Protection – This credit is applicable to homes that have opening protection and *also* have doors and garage doors protected with impact rated products. Note that the relativity results for the HVHZ already assume that the doors and garage doors are protected, and therefore are not eligible for this additional credit.
- Gable End Bracing – The results in Table 4-1 assumes that the Gable roofed homes (Other Roof Shape) are braced and do not fail. If new built houses have unbraced gables, the gable end bracing factor from Section 3.3.5 should be applied to the relativity.
- Foundation Restraint - Foundations built according to FBC are considered as restrained and therefore the unrestrained foundation adjustment factor is not applicable to new construction.

4.3.2 Mitigation and Over-Design of FBC Minimal Design Construction

Each of the designs prepared for the study buildings (summarized in Appendix E) meet the *minimum* requirements of the FBC. There are many opportunities in most parts of the state to exceed these requirements, and build to a higher design wind speed, or protect the building with opening protection. A builder may consider this when his geographic area of business extends across several wind speed regions, or the builder is attempting to differentiate his product from others in the area. It is also possible to add features that are not required by the building code, such as Secondary Water Resistance (SWR). For these conditions, the relativities shown in Table 4-1 should be adjusted with factors from Table 4-2.

To determine the change in relativity for these cases, the 6 study houses in each wind region were redesigned for higher wind speeds. Then the re-designed houses were re-run at typical points in each basic wind speed region. For each location, the design of the house was changed from its minimum wind speed design to a higher design wind speed in increments of 10 mph. Each house was also run with opening protection (if none existed previously) and with/without SWR. The results were then normalized by the results from the minimum wind speed table (Table 4-1) to produce Table 4-2. The column labeled as "Location Wind Speed and Exposure" in Table 4-2 lists the minimum wind speed region from Table 4-1.

These tables show that the biggest factor is the addition of opening protection, which offer between 15-20% additional savings from the minimal design case. Also, homes in the 100 mph region with no opening protection could benefit by approximately 10% when built higher wind speed.

To use these tables, one must know the minimum wind speed zone for where the house is located, and also the design wind speed for which the structure was actually designed. For example, if the house is located in Mid Florida Lakes, the minimum wind speed zone for that location is 100 mph, exposure B. Now, lets say the house was actually designed for 120 mph, Exposure C wind loads, and also has hurricane opening protection. For a gable house the adjusted relativity would be a simple multiplication

$$R' = R_{min} \cdot N_i \tag{4-1}$$

when R_{min} = 0.76 (relativity for FBC minimal design in Table 4-1) and N_i = 0.80 from Table 4-2. This multiplication produces R′ = 0.61

4.4 Verification Issues for New Construction

FBC Section 1606.17 summarizes the required wind load information that must be shown on construction drawings:

1. Basic Wind Speed
2. Wind Importance Factor and Building Category
3. Terrain Exposure
4. Applicable Internal Pressure Coefficient
5. Design Wind Pressure of Components and Cladding.

With this information and the following additional data (from the drawings or certified by the design professional)

1. Location of Building
2. Wall Construction
3. Roof Deck Type
4. Roof Shape
5. Additional Mitigation Factors (all openings protected, SWR),

one can properly rate the building. All of these items may be summarized on a form to be completed by the design professional and/or verified by a trained inspector.

Table 4-2. Modification Factors (N_i) for Over-Design and/or Mitigation of New Construction FBC Homes (2% Deductible)

Location Wind Speed and Exposure[1]	Wind Speed of Design[2] (mph)	Other Roof Shape				Hip Roof Shape			
		No Opening Protection		Opening Protection		No Opening Protection		Opening Protection	
		No SWR	SWR	No SWR	SWR	No SWR	SWR	No SWR	SWR
100 mph - Exposure B	100	1.00	0.98	0.81	0.81	1.00	0.99	0.86	0.86
	110	0.90	0.90	0.80	0.80	0.98	0.98	0.86	0.85
	≥ 120	0.89	0.88	0.80	0.80	0.98	0.97	0.85	0.85
110 mph - Exposure B	110	1.00	0.97	0.80	0.78	1.00	0.98	0.82	0.81
	≥ 120	0.94	0.91	0.79	0.77	0.99	0.97	0.81	0.80
≥ 120 mph - Exposure B	≥ 120	1.00	0.96	0.83	0.80	1.00	0.98	0.82	0.81
≥ 120 mph - Exposure C	≥ 120	1.00	0.88	0.79	0.71	1.00	0.91	0.78	0.72
HVHZ	HVHZ			1.00	0.73			1.00	0.80

[1] Wind Speed and Exposure for where house is located.

[2] Wind Speed that house is designed or mitigated to withstand.

5.0 BUILDING STOCK DISTRIBUTION FOR EXISTING CONSTRUCTION

5.1 Introduction

This section provides information on the distribution of Florida's building stock for single-family residences. A procedure is presented that uses year-built information for each risk coupled with statistical data obtained from Florida's Residential Construction Mitigation Program. Users should note that the estimation of the distribution of business as part of a new classification system must necessarily involve judgments. The estimates provided herein are subject to estimation errors from the limited data in many regions of the state. Improved estimates of the Florida building stock are expected to evolve as more buildings are inspected over the next few years.

The detailed work for this section is summarized in Appendix I. Appendix I provides the basic analysis for existing construction and how the state is divided into regions and construction eras. Section 5.2 discusses a "best estimate" approach used herein. Section 5.3 discusses the data sources used to estimate the building stock distribution. Section 5.4 summarizes the regions and eras used to estimate distribution of business. Section 5.5 presents examples of an average rating factor calculation for the primary rating factors.

5.2 Quantifying a "Best Estimate" of an Insurer's Distribution of Business

The building stock distribution estimated herein is aimed at quantifying a best estimate of wind resistive features by region within Florida. It is being provided to aid in the accurate classification of risks and quantification of impacts from implementing a mitigation classification system when there is an absence of other reasonable information. For any specific insured book of business, there may be other ways to estimate the distribution of business which an individual company might be able to determine.

Our approach makes no assumptions on how the insurer goes about rating its business. However, it is important to note that if all of the houses in an insurance portfolio are not accurately rated, then the distribution of business on the "books" for that insurer may be significantly different from its true distribution of business. For example, if only a small percentage of risks are accurately rated in the first year and the rest are by default classified in the weakest class, then that book of business will obviously not reflect the true distribution of wind resistive features. This dynamic complicates the estimation of average rating factors and may require realistic estimates of the annual rate of capture of wind resistive features on existing construction for those users that choose to lump all non-inspected risks into a single rate class. This fact is mentioned to make it clear that the focus of this section is on a procedure to estimate the "true" distribution of building stock in Florida. No assumptions are made regarding how a user chooses to capture the needed data or the rate at which a company captures the rating information.

The tables developed in Appendix I require the user to know the year built of each risk. With that information, a user can easily produce its own distribution of business tables for each of its rating territories. If a user does not have year built information, then this report includes a set of pre-computed average rating factors (for primary rating factors only) that are based on the year built data obtained from the Florida Department of Revenue (property tax records). However, it is clearly desirable for each user to produce its own estimate of its distribution of business since the tax record year-built information may not be representative of any single portfolio.

A second comment is in order regarding the quantification of the distribution of business. The work herein is based on using frequency (counts of individual houses), as was done in the FWUA class plan filing. Frequency is used herein because accurate insured values were not always available for the RCMP houses that were inspected. The use of frequency gives a measure of average rating factor for a territory on a per house basis. An alternative method is to use aggregate insured value instead of simply counting the frequency. That is, the distribution of business could be estimated by computing the aggregate insured values by territory and year built eras. With this approach, the normalization is by total insured value instead of by the total frequency count. This method probably gives a better estimate of the effect of average rating factor on the total premium base for a company.

5.3 Data Sources

Several sources of information are used to construct a building stock model. None of these sources are complete, non-biased, or error-free; hence, we must also use large amounts of judgment, particularly in the non-coastal areas of the state. The data sources considered in this project include the following:

1. **The Residential Construction Mitigation Program.** The Residential Construction Mitigation Program (RCMP) is a program administered by the Florida Department of Community Affairs. It is aimed at promoting hurricane mitigation in the state of Florida. In 1997, the RCMP program initiated a house inspection/mitigation analysis program to gather data on Florida homes and to evaluate these houses for cost-effective mitigation options. The program began in 1997 and by 1998 inspections and mitigation analyses of individual homes was begun in SE Florida. The program moved to the Panhandle (and Lee County) in 1999 and the Tampa Bay area in 2000.

   As part of the RCMP, reinspections were performed on a sample of houses to evaluate data quality and to determine how to improve the training of inspectors from year-to-year. The RCMP inspection forms evolved from year-to-year and the training of the inspectors improved significantly from 1998 to 1999. Table 5-1 summarizes the number of single-family RCMP inspections completed as of last year. Figure 5-1 shows a map of the counties where RCMP inspections were conducted. Analyses of these results provide the primary data source for estimating Florida's building stock of wind-resistive features of existing homes. Appendix G provides a summary of the raw (uncorrected) RCMP data by region.

2. **Florida Tax Records.** The Standard NAL (Name, Address, Legal) files were obtained from the Florida Department of Revenue. These files give information on year built, tax values, and other information. This data has been analyzed to provide an independent source of year built information by county. Users may want to compare these distributions of year built to their portfolio. Alternately, if an insurer's year built information is missing or not reliable, this source may prove to be a useful surrogate. Appendix H summarizes the year built tax revenue data by county.

3. **FWUA Database of Inspected Homes.** Since the introduction of the FWUA class plan in June 2000, thousands of homes have been inspected for the purposes of determining the appropriate rating class per the FWUA class plan. A portion of this database has been

Table 5-1. RCMP Inspections by County

Year	RCMP Location	County	Number of Inspections	Total Inspections	Number of Reinspections
1998	Southeast Florida	Broward	335		
		Dade	233		
		Palm Beach	488	1056	229
1999	Panhandle	Bay	48		
		Escambia	276		
		Gulf	24		
		Okaloosa	159		
		Santa Rosa	175		
		Walton	27		
	Lee	Lee	65	774	79
2000	Tampa Bay Area	Hillsborough	5		
		Manatee	37		
		Pasco	110		
		Pinellas	149	301	25
Total				2131	333

analyzed. Figure 5-2 shows the counties covered by a sample of FWUA inspection data evaluated in this study. This database is a biased sample of the building stock since it represents only those homeowners who have taken the initiative and expense of getting their homes inspected. Nevertheless, it is clearly a valuable resource because of the reasonably good quality of the inspections and the greater diversity of the coastal locations than available from the RCMP. Of course, like the RCMP data, this data does not provide information for the interior counties in the state. This data is used primarily as a source to help identify homogenous regions.

Each of these databases has limitations and, hence, a fair amount of judgment is required to develop a statewide model of the building stock. The RCMP database covers 3 regions in the state and there were some data quality problems, particularly in the first year of the program. It also is focused primarily near the coastline although there were a limited number of inland locations. The tax record database year built information is a mixture of actual year built and year of major improvement. The FWUA data is limited to the coastline and is not based on a random sample of policies.

5.4 Summary of "Best Estimate" of Building Stock Distribution

Building construction practices have changed over time as new materials, construction techniques, building codes and architectural styles have changed. In addition, local practices vary in different parts of the state, reflecting the different wind climates, rainfall, termite considerations, population density, value of land, etc. Neighborhoods in south Florida are different that those in north Florida. The objective of this analysis is to capture important differences in the existing business building stock using available information.

This analysis has been done in two parts. The first part has been to investigate the RCMP data and the FWUA data to determine if there are important differences in the building

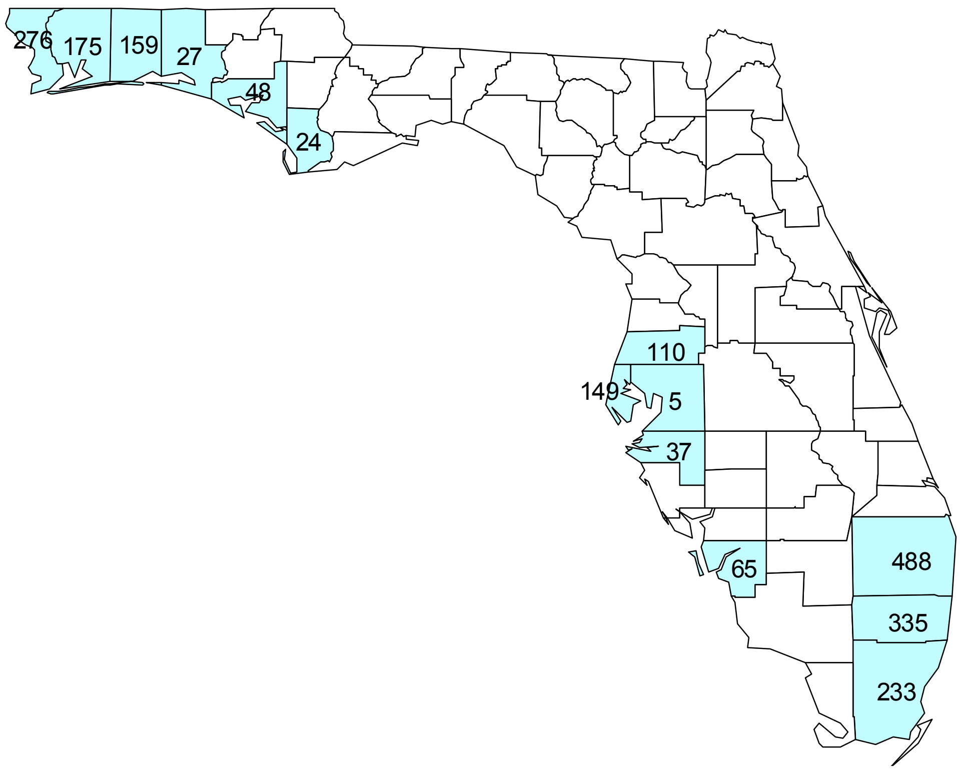


Figure 5-1. Map of RCMP Counties (1998-2000) and Number of Inspections in Each

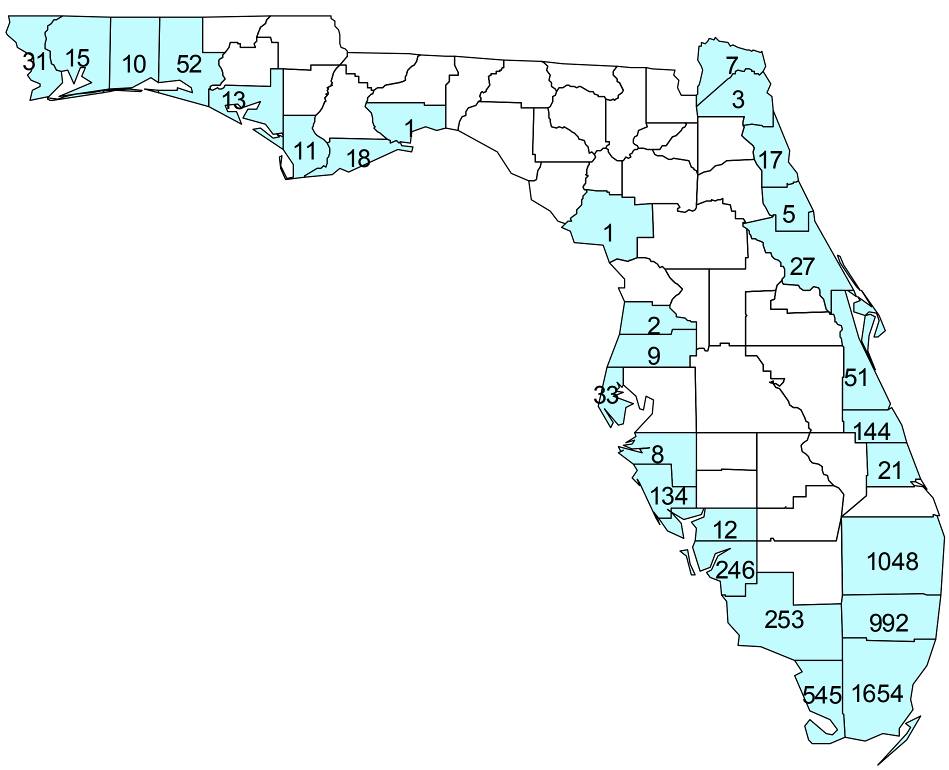


Figure 5-2. Subset of FWUA Class Plan Inspections

stock distribution according to year built and location within the state. The basic assumption is that the insurer has reasonably accurate information on year built and location of each of its residential lines policies. Hence, in the absence of other data or supplemental studies, an insurer can construct portfolio-specific frequency tables of its estimated true distribution of business using its year-built data. Once the regions and construction eras are identified, the second part of the analysis develops the distribution of business tables for each region and era. Please refer to Appendix I for the methods and details.

Florida Regions and Eras. Loss costs vary by location in the state and this variation is captured by insurance company rating territories. The relativities in Section 3 are applicable statewide. However, the building stock distribution clearly varies by region in the state and cannot be accurately reflected in a single statewide table. As discussed in Appendix I, four regions have been identified for purposes of estimating the building stock distribution. These regions are identified in Figure 5-3. Table 5-2 provides the list of counties for each Region.

The analysis in Appendix I suggests that construction materials and practices in Florida can be practically grouped into two "eras" or time periods for most of the state. These eras can be divided into pre-plywood construction and post plywood/OSB construction. The time period that the introduction of plywood began was the 1950s and by about 1965 over half of all new construction used plywood for roof decking. Similarly, in the same time frame metal roof-to-wall connectors became much more common, particularly in coastal construction. In SE Florida, a third era is needed to capture the significant improvements brought about by the 1994 SFBC. These eras are summarized in Table 5-3.

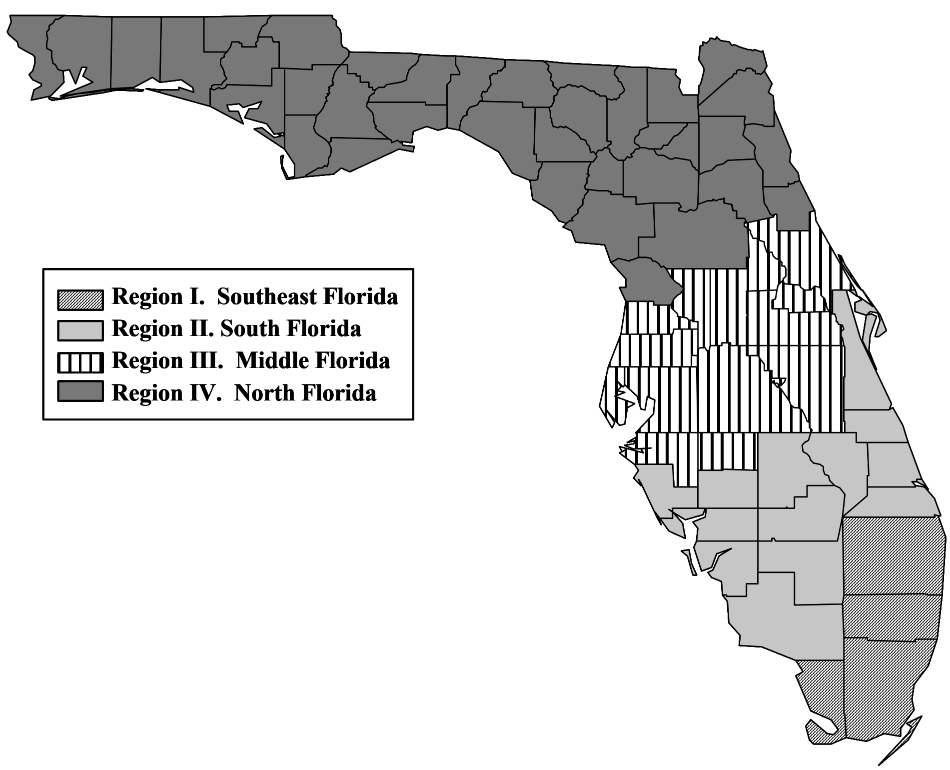


Figure 5-3. Florida Building Stock Regions

Table 5-2. Counties in Each Building Stock Region

Region	Number of Counties	Counties
I. Southeast Florida	4	Palm Beach, Broward, Miami-Dade, and Monroe
II. South Florida	13	Brevard, Indian River, Saint Lucie, Martin, Okeechobee, Highlands, Desoto, Sarasota, Charlotte, Glades, Lee, Hendry, and Collier
III. Mid Florida	13	Volusia, Lake, Sumter, Hernando, Pasco, Pinellas, Seminole, Orange, Hillsborough, Polk, Osceola, Manatee, and Hardee
IV. North Florida	37	Escambia, Santa Rosa, Okaloosa, Walton, Holmes, Washington, Bay, Jackson, Calhoun, Gulf, Gasden, Liberty, Franklin, Leon, Wakulla, Jefferson, Madison, Taylor, Hamilton, Suwannee, Lafayette, Dixie, Columbia, Oilchrist, Levy, Citrus, Baker, Union, Bradford, Alachua, Marion, Clay, Putnam, Nassau, Duval, Saint Johns, and Flagler

Table 5-3. Regions and Eras of Florida Residential Building Stock

Region	Year Built Eras
I. Southeast Florida	<1965, 1966-1994, ≥1995
II. South Florida	≤1965, >1966
III. Middle Florida	≤1965, >1966
IV. North Florida	≤1965, >1966

The distributions of building stock by region and era are given in Appendix I. Coupled with the insurer's distribution of business by year-built for each region or rating territory, average rating factors can be easily computed as described in the following section.

5.5 Example Computation of Average Rating Factors

The average primary rating factor for a region, construction era, and terrain is computed by

$$E_{era}\left(R\right)=\sum_{i=1}^{m} R_i\, P\left(R_i\right) \qquad (5\text{-}1)$$

where R_i is from Table 3-2 (Terrain B) or Table 3-3 (Terrain C) and $P(R_i)$ is the probability of a house having the i^{th} set of rating characteristics (i.e., the probability of a house having the i^{th} set of wind resistive features). Tables I-6 through I-14 provide estimates of $P(R_i)$. This equation is simply an expected value calculation.

The results of average rating factor computations for each region, era, and terrain are given in Table 5-4. These estimates are based on a very limited database to estimate the $P(R_i)$, as described in Appendix I.

To estimate average rating factors for a region or territory, the user can analyze portfolio-specific year-built information. This will produce $P_j(Era)$, which is the probability of a house in the region/territory being built in the j^{th} era. Then, the average rating factor for a portfolio and region can be computed by

$$E_{Region}(R) = \sum_{j=1}^{t} P_j\left(Era\right) E_{era}\left(R\right) \quad . \qquad (5\text{-}2)$$

Table 5-5 summarizes an example average rating factor calculation for a region or territory. The tax record database (Appendix H) is used in this example to get year-built frequency, $P_i(Era)$. State-wide average rating factors for Terrain B and C are also given for illustration purposes.

The above examples do not include the effect of secondary rating factors. Also, the tax record building stock frequency by region in Table 5-5 may not be representative of any single portfolio.

Table 5-4. Average Primary Rating Factors by Era for Each Region

Terrain	Region[1]	Average Primary Rating Factors, $E_{era}(R)$[3] ≤1965	1966-94[2]	≥1995
B	I	1.132	0.986	0.494
	II	1.388	1.074	
	III	1.600	1.216	
	IV	1.553	1.190	
C	I	0.917	0.841	0.295
	II	1.093	0.907	
	III	1.207	1.014	
	IV	1.195	1.036	

[1] See Figure 5-3.
[2] This era corresponds to 1966-2001 for Regions II, III, and IV.
[3] Computed using Eqn. 5-1.

Table 5-5. Example Average Primary Rating Factors by Region and Statewide

Terrain	Region	$P_i(Era)$ ≤1965	1966-94	≥1995	$E_{Region}(R)$[2]	$P(Region)$[3]	Statewide[4] $E_{state}(R)$
B	I	0.371	0.539	0.09	0.996	0.228	
	II	0.192	0.808	-	1.134	0.174	
	III	0.267	0.733	-	1.318	0.367	
	IV	0.289	0.711	-	1.295	0.231	
	All					1.000	1.207464
C	I	0.371	0.539	0.09	0.820	0.228	
	II	0.192	0.808	-	0.943	0.174	
	III	0.267	0.733	-	1.065	0.367	
	IV	0.289	0.711	-	1.082	0.231	
	All					1.000	0.991989

[1] Example data only, based on analysis of Florida Tax Records for Year-built (Appendix H); the fractions for each Region sum to unity across eras.
[2] Computed by Eqn. 5-2 using Florida Tax Record Year-built data.
[3] Example data from Florida Tax Record to get distribution of houses by Region.
[4] Example calculations only, based on tax record data.

6. SUMMARY

6.1 General

A research project has been conducted to estimate the effects of wind-resistive building features in reducing hurricane damage and loss to single family residential structures located in the state of Florida. The scope of this project has included both new construction to the Florida Building code 2001 and existing construction. An analysis of the building stock distribution for existing construction has also been developed.

The results of this study are based on the analysis of individually modeled buildings at numerous locations in Florida. Each building has been modeled with a specific set of wind resistive features. The features considered in this project include: roof shape, roof covering, secondary water resistance, roof-to-wall connection, roof deck material/attachment, opening protection, gable end bracing, wall construction, and wall-to-foundation restraint. For new construction, the buildings have been designed to the FBC 2001 according to the design wind speed, wind-borne debris region design options, and FBC definitions of Terrain Category. In the wind-borne debris region, designs for both enclosed and partially enclosed structures have been evaluated, per the FBC and ASCE 7-98.

The remainder of this section attempts to summarize key information. However, careful review of the report and Appendices is recommended.

6.2 Florida Building Code

The Florida Building Code (FBC) is the central piece of a new statewide building code system. The single statewide code is developed and maintained by the Florida Building Code Commission. The FBC supersedes all local codes and is automatically effective on the date established by state law. The new building code system requires building code education requirements for all licensees and uniform procedures and quality control in a product approval system.

The FBC 2001 will have a notable impact on new construction in the state of Florida. The code is expected to improve the design and construction of new buildings with regard to wind loads, particularly in the windborne debris regions. The key impacts of the FBC on residential construction include:

1. A Wind-Borne-Debris Region (WBDR) that encompasses a significant part of the state.
2. Adoption of ASCE 7-98 Terrain Exposure Categories, with some exceptions.
3. Options for Partially-Enclosed and Enclosed Design in WBDR.
4. HVHZ in Miami-Dade and Broward Counties; enclosed design required in HVHZ.
5. Opening protection in WBDR applies to glazed openings, except that all openings must be protected in HVHZ.
6. Load combinations for ASCE 7-98 for Allowable Stress Design will result in larger connection sizes for roof-to-wall connections.
7. Chapter 34 requires houses that are damaged beyond 25% to be repaired according to the FBC. For houses damaged beyond 50%, the entire building must be repaired to conform to the FBC.

The wind speed map for the FBC is repeated in Figure 6-1. The Wind-Borne Debris Region includes all areas where the basic wind

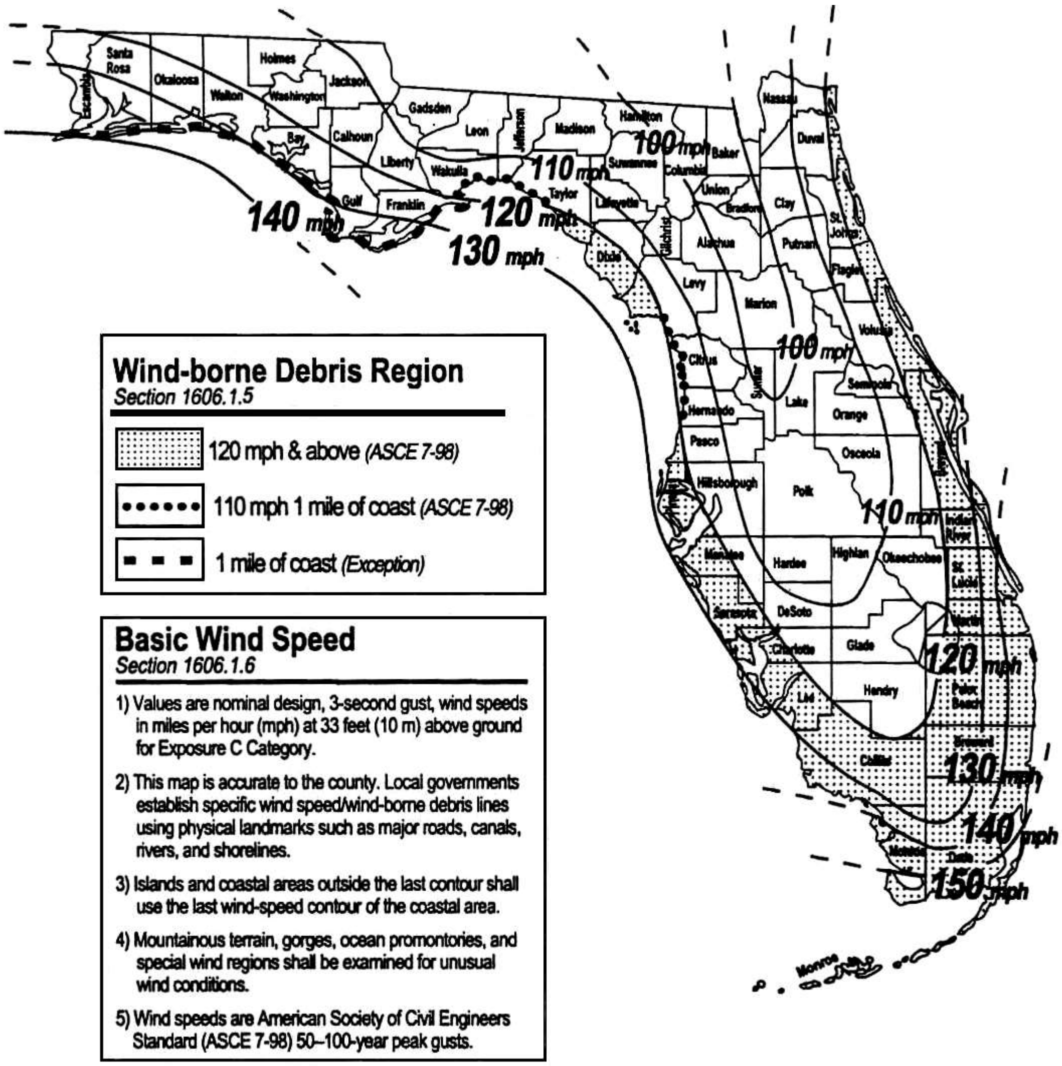


FIGURE 1606
STATE OF FLORIDA
WIND-BORNE DEBRIS REGION & BASIC WIND SPEED

Figure 6-1. Wind Regions in Florida Building Code

speed is 120 mph or greater except for Panhandle area where the region includes areas only within 1 mile of the coast. The FBC adopted the Terrain Exposure Categories of the ASCE 7-98 with a few exceptions. Terrain Exposure C (open terrain) applies to all locations in Miami-Dade and Broward Counties (the High Velocity Hurricane Zone, HVHZ), barrier islands, and all locations within 1500 ft of the coastline. Terrain Exposure B (urban, suburban, and wooded areas) applies to all other locations in Florida.

Discussion of the FBC and its impact on construction of single family residential buildings is contained in Sections 2.2, 4.1, 4.2, and Appendix E. Appendix F contains one example set of FBC design of a single family residence used in the calculation of loss relativities.

6.3 Loss Relativities for Existing Construction

The loss costs relativities for existing construction are developed in the form of a set of tables. Two main tables are provided for the seven primary rating factors, one set for Terrain B (Table 6-1) and one set for Terrain C (Table 6-2). These tables are normalized to a "central" house, which is a representative house as opposed to the weakest house. The relativity for the central house is one. The Terrain B results are primarily for inland locations and the Terrain C results are primarily for barrier islands and locations within 1500 feet of the coastline.

Table 6-3 summarizes a simple description of these primary rating factors in Tables 6-1 and 6-2.

A set of secondary rating factors have been developed that are used as multipliers to the relativities for the primary rating factors in Tables 6-1 and 6-2. Table 6-4 summarizes these adjustments, Table 6-5 gives the relativities for houses with reinforced concrete roof decks.

These secondary adjustments are applied using

$$R' = \prod_i K_i R_i \qquad (6\text{-}1)$$

where K_i is the adjustment factor given in Tables 6-4 or 6-5, and R_i is the appropriate relativity from Table 6-1 or 6-2. See Section 3.3.7 for examples of secondary rating factor adjustments.

The loss relativities in Tables 6-1 through 6-5 are based on loss costs corresponding to 2% deductibles. Deductibles affect the relativities in different ways, depending on the strength of the house. In general, the loss costs for stronger houses (small relativities) are more sensitive to deductible since the damage to these houses is often exterior and roof covering damage. There are several options available to a user to make adjustments to these relativities to reflect deductibles other than 2%. Section 3.5 presents an example procedure to adjust relativities for other deductibles.

Refer to Section 3 and Appendix C to fully appreciate the issues associated with implementation of these rating factors for existing construction.

6.4 Loss Relativities for New Construction to FBC 2001

For new construction to the Florida Building Code 2001, the loss relativities have been computed and reduced to a single table for minimal design loads (Table 6-6). This table is applicable only to houses built to minimal loads of FBC 2001.

The top part of the table covers all new construction that does not have a reinforced concrete roof deck. This applies to well over 99% of new construction. The lower portion applies only to new FBC houses with a reinforced concrete roof deck built to ACI 318 and tied integrally to reinforced masonry walls.

The analysis indicates that there is a small difference in relativity between an enclosed design without opening protection and a partially enclosed design (also without opening protection). Hence, in Table 6-7, there is only a small difference in enclosed and partially enclosed designs.

Also note that Opening Protection in Terrain Exposure B and Exposure C means that all glazed openings (i.e., those with glass or plastic) are protected with impact-rated glazing or shutters. The requirements for the High Velocity Hurricane Zone (HVHZ) are slightly different in that all openings, including doors and garage doors, must be protected with shutters or impact resistant products. The results in Table 6-7 include protection requirement for all openings that are required in the HVHZ.

Footnote 9 in Table 6-6 summarizes the possible secondary adjustments to the new construction relativities. These are applied as multipliers as described above for existing construction.

Table 6-1. Loss Costs Relativities– Terrain B Locations with 2% Deductible

Terrain Category B – 2% Deductible				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A	Toe Nails	None	2.37	2.22	1.26	1.18
			Basic	1.53	1.37	0.91	0.83
			Hurricane	1.33	1.15	0.80	0.71
		Clips	None	1.55	1.37	0.91	0.80
			Basic	1.26	1.08	0.75	0.65
			Hurricane	1.19	1.01	0.72	0.61
		Single Wraps	None	1.53	1.35	0.91	0.79
			Basic	1.25	1.07	0.75	0.65
			Hurricane	1.19	1.00	0.72	0.61
		Double Wraps	None	1.53	1.35	0.91	0.80
			Basic	1.25	1.07	0.75	0.65
			Hurricane	1.19	1.00	0.72	0.61
	B	Toe Nails	None	2.16	2.05	1.22	1.14
			Basic	1.27	1.17	0.88	0.81
			Hurricane	1.04	0.92	0.76	0.68
		Clips	None	**1.00**	0.84	0.76	0.64
			Basic	0.84	0.71	0.65	0.56
			Hurricane	0.80	0.66	0.63	0.55
		Single Wraps	None	0.95	0.76	0.75	0.64
			Basic	0.79	0.64	0.64	0.55
			Hurricane	0.77	0.63	0.63	0.55
		Double Wraps	None	0.94	0.76	0.75	0.64
			Basic	0.79	0.63	0.64	0.55
			Hurricane	0.77	0.62	0.63	0.55
	C	Toe Nails	None	2.15	2.04	1.22	1.15
			Basic	1.27	1.16	0.88	0.81
			Hurricane	1.03	0.92	0.75	0.68
		Clips	None	0.98	0.82	0.75	0.64
			Basic	0.82	0.70	0.64	0.56
			Hurricane	0.78	0.66	0.63	0.55
		Single Wraps	None	0.91	0.73	0.75	0.63
			Basic	0.77	0.63	0.64	0.55
			Hurricane	0.75	0.62	0.63	0.55
		Double Wraps	None	0.90	0.72	0.75	0.63
			Basic	0.75	0.61	0.64	0.55
			Hurricane	0.74	0.61	0.63	0.54
FBC Equivalent	A	Toe Nails	None	2.11	2.05	1.07	1.04
			Basic	1.26	1.22	0.71	0.69
			Hurricane	1.03	0.99	0.59	0.57
		Clips	None	1.22	1.19	0.67	0.65
			Basic	0.94	0.91	0.53	0.51
			Hurricane	0.88	0.84	0.49	0.47
		Single Wraps	None	1.21	1.18	0.67	0.65
			Basic	0.94	0.90	0.53	0.51
			Hurricane	0.87	0.84	0.49	0.47
		Double Wraps	None	1.21	1.17	0.67	0.65
			Basic	0.93	0.90	0.53	0.51
			Hurricane	0.87	0.83	0.49	0.47
	B	Toe Nails	None	1.95	1.90	1.03	1.01
			Basic	1.06	1.02	0.69	0.67
			Hurricane	0.80	0.78	0.56	0.55
		Clips	None	0.72	0.69	0.53	0.50
			Basic	0.59	0.56	0.44	0.42
			Hurricane	0.54	0.51	0.43	0.41
		Single Wraps	None	0.65	0.61	0.52	0.50
			Basic	0.53	0.49	0.43	0.41
			Hurricane	0.51	0.48	0.43	0.41
		Double Wraps	None	0.65	0.60	0.52	0.50
			Basic	0.52	0.48	0.43	0.41
			Hurricane	0.51	0.47	0.43	0.41
	C	Toe Nails	None	1.94	1.89	1.03	1.01
			Basic	1.05	1.02	0.69	0.67
			Hurricane	0.80	0.77	0.56	0.55
		Clips	None	0.70	0.67	0.52	0.50
			Basic	0.58	0.55	0.44	0.42
			Hurricane	0.53	0.51	0.43	0.41
		Single Wraps	None	0.62	0.58	0.52	0.49
			Basic	0.51	0.48	0.43	0.41
			Hurricane	0.49	0.47	0.42	0.41
		Double Wraps	None	0.61	0.57	0.52	0.49
			Basic	0.50	0.46	0.43	0.41
			Hurricane	0.49	0.46	0.42	0.41

Notes: 1. This table is based on averaging the relativities for each of the three modeled houses (with composition shingle roof coverings) for all 17 Terrain B locations.
2. This table applies to single family houses in Terrain B except those with a reinforced concrete roof deck.
3. Secondary factors are not considered in this table, including: (i) board roof decks (dimensional lumber and tongue and groove); (ii) masonry walls and reinforced masonry walls; (iii) all openings protected versus just glazed opening protected; (iv) unbraced gable end for gable roofs (other roof shape); and (v) unrestrained foundation.

Table 6-2. Loss Costs Relativities– Terrain C Locations with 2% Deductible

Terrain Category C – 2% Deductible				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A	Toe Nails	None	1.60	1.49	1.16	1.09
			Basic	1.13	0.99	0.71	0.61
			Hurricane	0.98	0.83	0.57	0.45
		Clips	None	1.31	1.19	0.89	0.79
			Basic	0.99	0.83	0.58	0.45
			Hurricane	0.90	0.73	0.51	0.38
		Single Wraps	None	1.28	1.15	0.88	0.78
			Basic	0.97	0.81	0.58	0.45
			Hurricane	0.90	0.73	0.51	0.38
		Double Wraps	None	1.27	1.15	0.88	0.78
			Basic	0.97	0.81	0.58	0.45
			Hurricane	0.90	0.73	0.51	0.38
	B	Toe Nails	None	1.46	1.37	1.13	1.07
			Basic	0.89	0.80	0.65	0.58
			Hurricane	0.72	0.62	0.50	0.42
		Clips	None	**1.00**	0.89	0.69	0.56
			Basic	0.60	0.47	0.43	0.33
			Hurricane	0.49	0.35	0.39	0.28
		Single Wraps	None	0.84	0.68	0.64	0.47
			Basic	0.53	0.38	0.41	0.30
			Hurricane	0.48	0.32	0.38	0.28
		Double Wraps	None	0.79	0.59	0.63	0.45
			Basic	0.51	0.34	0.41	0.29
			Hurricane	0.47	0.31	0.38	0.27
	C	Toe Nails	None	1.45	1.37	1.13	1.07
			Basic	0.88	0.79	0.65	0.58
			Hurricane	0.71	0.62	0.50	0.42
		Clips	None	0.98	0.88	0.69	0.56
			Basic	0.57	0.46	0.43	0.33
			Hurricane	0.46	0.34	0.38	0.28
		Single Wraps	None	0.81	0.64	0.63	0.44
			Basic	0.49	0.36	0.40	0.29
			Hurricane	0.43	0.30	0.38	0.27
		Double Wraps	None	0.72	0.47	0.62	0.41
			Basic	0.45	0.30	0.39	0.27
			Hurricane	0.42	0.28	0.37	0.26
FBC Equivalent	A	Toe Nails	None	1.49	1.44	1.07	1.03
			Basic	0.97	0.93	0.59	0.56
			Hurricane	0.81	0.77	0.43	0.40
		Clips	None	1.16	1.12	0.75	0.73
			Basic	0.80	0.76	0.43	0.39
			Hurricane	0.71	0.67	0.36	0.32
		Single Wraps	None	1.12	1.09	0.75	0.72
			Basic	0.79	0.74	0.43	0.39
			Hurricane	0.71	0.66	0.36	0.32
		Double Wraps	None	1.12	1.08	0.75	0.72
			Basic	0.78	0.74	0.43	0.39
			Hurricane	0.71	0.66	0.36	0.32
	B	Toe Nails	None	1.36	1.32	1.04	1.01
			Basic	0.78	0.75	0.55	0.53
			Hurricane	0.60	0.57	0.38	0.36
		Clips	None	0.87	0.84	0.54	0.51
			Basic	0.46	0.42	0.31	0.28
			Hurricane	0.35	0.30	0.26	0.23
		Single Wraps	None	0.68	0.63	0.46	0.41
			Basic	0.38	0.33	0.28	0.24
			Hurricane	0.32	0.27	0.26	0.22
		Double Wraps	None	0.60	0.53	0.45	0.39
			Basic	0.35	0.29	0.27	0.23
			Hurricane	0.32	0.26	0.25	0.22
	C	Toe Nails	None	1.36	1.32	1.04	1.01
			Basic	0.78	0.74	0.55	0.53
			Hurricane	0.59	0.56	0.39	0.36
		Clips	None	0.86	0.83	0.54	0.50
			Basic	0.44	0.41	0.30	0.27
			Hurricane	0.32	0.29	0.26	0.23
		Single Wraps	None	0.64	0.59	0.45	0.39
			Basic	0.35	0.31	0.27	0.23
			Hurricane	0.29	0.25	0.25	0.22
		Double Wraps	None	0.51	0.41	0.43	0.36
			Basic	0.30	0.25	0.26	0.22
			Hurricane	0.28	0.23	0.25	0.21

Notes: 1. This table is based on averaging the relativities for each of the three modeled houses (with composition shingle roof coverings) for all 14 Terrain C locations.
2. This table applied so single family houses in Terrain C except those with a reinforced concrete roof deck.
3. Secondary factors are not considered in this table, including: (i) board roof decks (dimensional lumber and tongue and groove); (ii) masonry walls and reinforced masonry walls; (iii) all openings protected versus just glazed opening protected; (iv) unbraced gable end for gable roofs (other roof shape); and (v) unrestrained foundation.

Table 6-3. Primary Rating Factors for Existing Construction

Rating Factor	Category	Simple Description/Implementation	Discussion and Text Reference
Terrain	B	All locations that are not Terrain C	User needs to determine how to best deal with terrain for existing construction. See Section 2.2.2 and C.2.10.
	C	Barrier Islands and areas within 1500 feet of coast	Terrain C loss relativities can be used if user separately computes base loss costs for these locations. See Section 3.2.
Roof Shape	Other	All roofs that are not Hip	Includes gable, gable-hip, flat, mansard, and all others; unbraced gable ends get a separate addition factor applied. See Appendix C.2.5.
	Hip	Hip roofs or hip roofs with attached small flat roof	Flat roof portions are generally over small rooms.
Roof Covering	Non-FBC	All roof covers not installed to FBC 2001 or to 1994 SFBC	Appendix C.2.1. Also see Appendix C.3 for discussion on tile roof coverings.
	FBC	All roof covers installed to FBC 2001 or to 1994 SFBC	
Secondary Water Resistance (SWR)	No	No SWR	Standard underlayment or hot mopped felts are not SWR. See Appendix C.2.2.
	Yes	Self adhering polymer modified bitumen roofing underlayment or foamed structural adhesive installed over all roof deck joints to prevent water entry into the house after the roof covering itself fails.	
Roof-to-Wall Connection	Toe-Nails	Toe-nailed	See Appendix C.2.3.
	Clips	Clips and Diamond connectors	
	Wraps	Single-sided strap wrap	
	Double Wraps	Wrap two sides	
Roof Deck Attachment	A	Typically 6d nails at 6”/12” spacing	See Appendix C.2.4. Concrete roof decks are considered in separate table; dimensional lumber board decks get an additional reduction factor (Table 6-4).
	B	Typically 8d nails at 6”/12” spacing	
	C	Typically 8d nails at 6”/6” spacing	
Opening Protection	None	Glazed openings not protected for impact resistance.	See Appendix C.2.7; if all openings (not just glazed) are protected, an additional reduction factor is applied (Table 6-4).
	Basic	All glazed openings protected to the 4.5 lb missile in ASTM E 1996	
	Hurricane	All glazed openings protected to Miami Dade PA 201,202, and 203; SSTD 12; or ASTM E 1886 and E 1996 (Missile C)	

Table 6-4. Adjustments to Loss Relativities

Factor	Reference Cell in Tables 6-2 or Table 6-3	Relativity Adjustment Factor (K_i)
Dimensional Lumber Deck	Deck Attachment C	0.96
Masonry Walls	Any	0.98
Reinforced Masonry Walls	Any	0.95
Reinforced Concrete Roof Deck	None	Use Table 6-5 for Relativities
Opening Coverage – All Openings	Basic or Hurricane	0.98
Unbraced Gable End	Any “Other” Roof Shape	1.02
Foundation Restraint	Any	Terrain B: 1.38 Terrain C: 1.54

Table 6-5. Loss Relativities – Reinforced Concrete Roof Deck[1]

Opening Protection Level	Terrain B - 2% Deductible	Terrain C - 2% Deductible
None	0.44	0.32
Basic	0.38	0.20
Hurricane	0.36	0.18

1 Integral with reinforced masonry wall; these relativities do not require further adjustment.

Table 6-6. Loss Relativities for Minimum Design Construction to FBC 2001 (2% Deductible)[1]

FBC 2001 Construction					Other Roof Shape		Hip Roof Shape	
Roof Deck	Terrain Exposure[2]	FBC Wind Speed[11] (mph)	Internal Pressure Design[3]	WBDR[4]	No Opening Protection	Opening Protection	No Opening Protection	Opening Protection
Other Roof Deck[9]	B	100	Enclosed	No	0.76	-[5]	0.51	-[5]
		110	Enclosed	No	0.66	-[5]	0.51	-[5]
		≥ 120	Enclosed	No	0.61[6]	-	0.52[6]	-
				Yes	-	0.48	-	0.41
			Part. Enclosed	Yes	0.60	-[7]	0.51	-[7]
	C	≥ 120	Enclosed	Yes	-	0.27	-	0.23
			Part. Enclosed	Yes	0.37	-[7]	0.30	-[7]
	HVHZ		Enclosed	Yes	-[8]	0.26	-[8]	0.23
Reinforced Concrete Roof Deck[10]	B	Any	Enclosed	No	0.44	-[5]	0.44	-[5]
				Yes	-	0.36	-	0.36
			Part. Enclosed	Yes	0.43	-[7]	0.43	-[7]
	C	Any	Enclosed	Yes	-	0.18	-	0.18
			Part. Enclosed	Yes	0.31	-[7]	0.31	-[7]
	HVHZ		Enclosed	Yes	-[8]	0.17	-[8]	0.17

1 Table is for houses built to Minimum Wind Loads of FBC 2001. Houses built to higher loads should use this table and the adjustments in Table 6-7.
2 See Fig. 6-1 and FBC 1606.1.8.
3 FBC 1606.1.4.
4 WBDR = Wind-Borne Debris Region (FBC 1606.1.5 and Section 2.2.1 of this report).
5 Not applicable to Minimum Load Design in non-WBDR.
6 This relativity applies to non-WBDR locations.
7 Not applicable to Minimum Load Design for Partially Enclosed Buildings in WBDR.
8 HVHZ requires WBD Opening Protection.
9 Secondary Rating Factors: applicable to "Other Roof Decks"
i. Dimensional lumber roof deck: K = 0.96
ii. Reinforced masonry walls: K = 0.95
iii. All openings protected in non-HVHZ: K = 0.98
iv. These factors are applied per Eqn. 6-1.
10 No secondary rating factor adjustments to these relativities.
11 FBC wind speed corresponding to house location.

Not all new construction will be designed and built to the minimal loads in the FBC. Builders will often duplicate a design and build the same house in a lower wind speed location. For example, a house designed for 120 mph may be built in a 100 mph region or a house in the non-windborne debris region may be built with opening protection. Alternately, the homeowner may mitigate his house at a later date with SWR or opening protection. A separate table of modification factors has been developed to handle these cases and this table is given as Table 6-7.

6.5 Building Stock Distribution of Existing Construction

Building construction practices have changed over time as new materials,

Table 6-7. Modification Factors for Over-Designed and Mitigation of New Construction Homes (2% Deductible)

Location Wind Speed and Exposure[1]	Wind Speed of Design[2] (mph)	Other Roof Shape				Hip Roof Shape			
		No Opening Protection		Opening Protection		No Opening Protection		Opening Protection	
		No SWR	SWR	No SWR	SWR	No SWR	SWR	No SWR	SWR
100 mph - Exposure B	100	1.00	0.98	0.81	0.81	1.00	0.99	0.86	0.86
	110	0.90	0.90	0.80	0.80	0.98	0.98	0.86	0.85
	≥ 120	0.89	0.88	0.80	0.80	0.98	0.97	0.85	0.85
110 mph - Exposure B	110	1.00	0.97	0.80	0.78	1.00	0.98	0.82	0.81
	≥ 120	0.94	0.91	0.79	0.77	0.99	0.97	0.81	0.80
≥ 120 mph - Exposure B	≥ 120	1.00	0.96	0.83	0.80	1.00	0.98	0.82	0.81
≥ 120 mph - Exposure C	≥ 120	1.00	0.88	0.79	0.71	1.00	0.91	0.78	0.72
HVHZ	HVHZ			1.00	0.73			1.00	0.80

[1] Wind Speed and Exposure for where house is located.

[2] Wind Speed that house is designed or mitigated to withstand.

construction techniques, building codes and architectural styles have changed. In addition, local practices vary in different parts of the state, reflecting the different wind climates, rainfall, termite considerations, population density, value of land, etc. Neighborhoods in south Florida are different that those in north Florida. The objective of the analysis in Section 5 and Appendix I is to capture important differences in the existing business building stock using information readily available to insurers.

The building stock distribution analysis for existing residences in Florida has been developed primarily from the Residential Construction Mitigation Program database of inspected homes. Four regions and three construction eras were identified to provide an approximate method for estimating the distribution of business. These regions are identified in Figure 6-2. Table 6-8 provides the list of counties for each Region.

The analysis in Appendix I suggests that construction materials and practices in Florida can be practically grouped into two "eras" or time periods for most of the state. These eras can be divided into pre-plywood construction and post plywood/OSB construction. The time period that the introduction of plywood began was the 1950s and by about 1965 over half of all new construction used plywood for roof decking. Similarly, in the same time frame metal roof-to-wall connectors became much more common, particularly in coastal construction. In SE Florida, a third era is needed to capture the significant improvements brought about by the 1994 SFBC. These eras are summarized in Table 6-9.

A procedure is included in Section 5 to estimate distribution of business. For a book of business, a user can compute the proportion of houses in a Florida portfolio by counting the houses in each region and construction era. This results is a portfolio-specific distribution of business. As an example, we have analyzed the Florida Tax Record database and produced a distribution of business by Region and Era in Section 5.

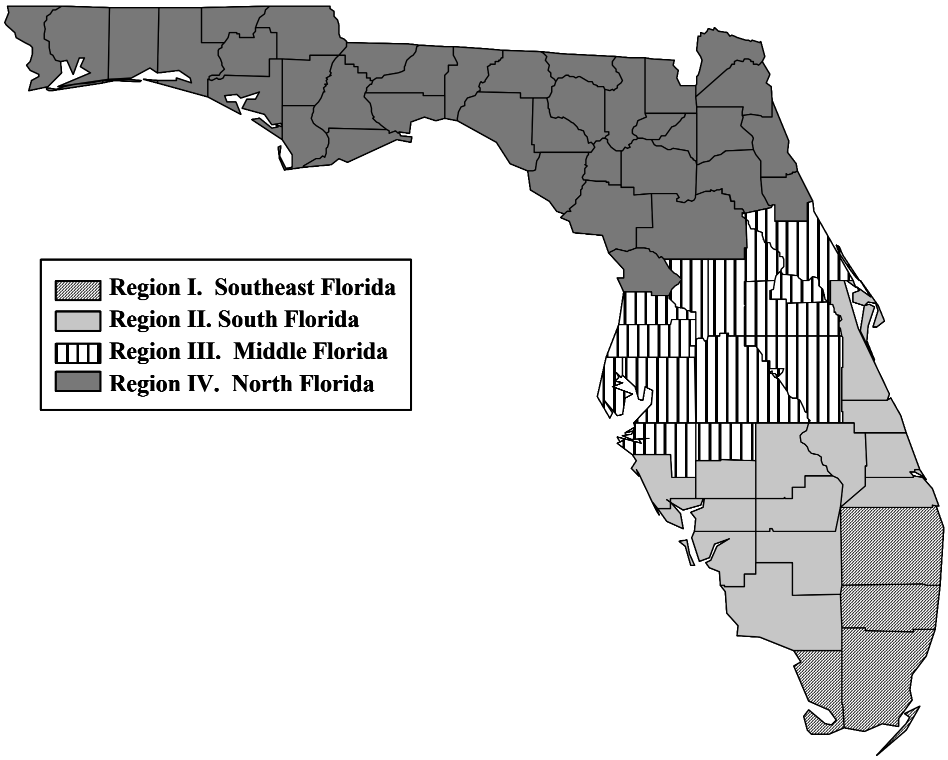


Figure 6-2. Florida Building Stock Regions

Table 6-8. Counties in Each Building Stock Region

Region		Number of Counties	Counties
I.	Southeast Florida	4	Palm Beach, Broward, Miami-Dade, and Monroe
II.	South Florida	13	Brevard, Indian River, Saint Lucie, Martin, Okeechobee, Highlands, Desoto, Sarasota, Charlotte, Glades, Lee, Hendry, and Collier
III.	Mid Florida	13	Volusia, Lake, Sumter, Hernando, Pasco, Pinellas, Seminole, Orange, Hillsborough, Polk, Osceola, Manatee, and Hardee
IV.	North Florida	37	Escambia, Santa Rosa, Okaloosa, Walton, Holmes, Washington, Bay, Jackson, Calhoun, Gulf, Gasden, Liberty, Franklin, Leon, Wakulla, Jefferson, Madison, Taylor, Hamilton, Suwannee, Lafayette, Dixie, Columbia, Oilchrist, Levy, Citrus, Baker, Union, Bradford, Alachua, Marion, Clay, Putnam, Nassau, Duval, Saint Johns, and Flagler

Table 6-9. Regions and Eras of Florida Residential Building Stock

Region		Year Built Eras
I.	Southeast Florida	<1965, 1966-1994, ≥1995
II.	South Florida	≤1965, >1966
III.	Middle Florida	≤1965, >1966
IV.	North Florida	≤1965, >1966

6.6 Limitations and Discussion

The following discussion represents the independent opinions of the ARA authors of this report and should not be interpreted as representing views of the State of Florida.

Wind Mitigation Features Not Considered. As described and discussed in Appendix C, there are some key variables not explicitly considered in this study. These include:

1. Building Height (single story residences were used throughout)
2. Tile Roof coverings (not considered in the modeled houses)
3. Skylights (all glazed openings were assumed to be protected or not protected)
4. Porches and carports

Other features, such as garage and variations in percent glazing, were treated in the modeled houses but were not analyzed as separate classification variables. See Appendix C for a discussion of each of these variables. A separate study on two and three story residences is needed to address loss relativities, coupled with developing data for building code improvements for buildings less than 30 feet in height.

Actuarial Judgments. The relativities computed herein do not include any “actuarial” types of adjustments. For example, no assumptions are made on the method to obtain the rating data or the accuracy of such rating data.

Uncertain Building Stock. The building stock distribution approach is based on limited data with some significant assumptions. A baseline of inspections is needed for the interior counties to aid the determination of regions and frequencies for those locations.

Wood Shutters. The Florida Building Code allows for the use of wood structural panels (fastened according to FBC loads) as opening protection in all locations except the HVHZ. This report does not include an analysis for wood structural panels. Detailed analysis of the available data, and possibly new impact and pressure cycling tests are recommended to fill this void. Users will have to use judgment or separate analysis for wood structural panels opening protection relativities. Wood structural panels may have relativities higher (corresponding to weaker construction) than the Basic Opening Protection results contained in this report.

Top Chord Failures of Gable End. The results for the secondary factor, Gable End Bracing, are based on analyzing bottom chord failures using a simple model. Top chord failures that occur distinct from the case of loss of roof deck attached to the end truss, have not been modeled. Experiments and further analysis would be needed to model this failure mode. While this is not expected to be a major factor, it is recommended that these types of top chord failures be analyzed and included in the loss relativities.

Individual Building Rating. The scope of this study has focused on specific wind loss mitigation features and relativities on a house-by-house basis. Such relativities, when applied, attempt to capture differences in loss costs for buildings with/without specific wind mitigation features. These relativities will obviously affect insurance rates on a house-by-house basis. However, these relativities are separate from an overall rate increase/decrease across a book of business.

Standardize Building Ratings. An effective way to communicate a house rating to the public should be standardized. This concept has been discussed for several years as part of the RCMP efforts and there are several good ideas to achieve this goal. It could be a numerical score coupled to a star rating system (up to 5 stars in half star increments), etc. that the public would understand. The system needs to be carefully developed so that it communicates the general wind mitigation rating of a building and is also tied approximately to loss reduction relativities/effects.

BCEGS. The scope of this study has not addressed any aggregate territorial type rating, such as BCEGS, that may apply to a entire county or territory. The use of a territory-wide rating system and an individual building rating system are not necessarily mutually exclusive. For new construction, the FBC calls for inspections during construction by building officials of anchorages of window and doors, foundations, etc., during the construction process. These features are not readily observable after the construction is complete. Hence, depending on the magnitude and rationale of the adjustments for a territory-wide rating system and how close it dovetails to the requirements of the FBC, these type of adjustments may be reasonable to consider in addition to separately applied loss relativities based on specific wind mitigation features. If the territory-wide adjustments are relatively small compared to the magnitude of the key loss relativity adjustments, then the combination of both may be reasonable. If the territory-wide adjustments are relatively large, then the combined territory-wide and individual building ratings may not be working together properly.

Additional Hurricane Damage Data. It is recommended that a public domain study be performed on analyzing damage and loss of a sample of buildings in each Category 3 and higher storm that makes landfall in Florida. Data needs to be collected for each storm on several hundred randomly selected buildings that document the construction features and physical damage of each building. When available, the loss claims would be obtained from each owner to individually document the loss (with insurance company name deleted). With proper analysis of building orientation (important for individual storms) and actual surrounding terrain, analyses of field/model estimated measures of loss relativity could be documented. Repeating this process for several Category 3 or higher hurricanes, improved measures of loss relativity for new and existing construction can be developed and demonstrated. Improvements to the building code and code enforcement may be identified. Because of the nonlinear nature of loss, the many building specific variables involved, and real terrain variations, simplistic efforts that look at a single storm are doomed to give incomplete if not misleading results without an associated analysis effort of building loads, resistances, and physical damage.

Cost-Benefit Analysis of Possible Improvements to the Florida Building Code. The Florida Building Code is a good step in the right direction for the State. It has certain wind mitigation features at a very modest cost increase. These improvements will reduce future losses in hurricanes. There are several additional areas where code improvements may have large benefits at modest cost impacts. These include: secondary water resistance; wind-borne debris protection to a new risk-based standard for regions not now covered by the WBDR; improved loads for two and three story buildings; reviewing the partially enclosed option; further improvements to roof coverings and attachments; improved wind loads in tall tree environments; and quantifying tree fall risk, damage, and loss to residences.

7. REFERENCES

ACI 530/ASCE 5/TMS 402-99, *Building Code Requirements for Masonry Structures*, American Concrete Institute, Farmington Hills, MI, 1999.

AF&PA/AWC, *Wood Frame Construction Manual for One- and Two-Family Dwellings,* 1995 SBC High Wind Edition, American Forest and Paper Association/American Wood Council, Washington, DC, 1996.

ANSI/AF&PA, *National Design Specification for Wood Construction* and *Design Values for Wood Construction*, a Supplement to the National Design Specification, American Forest and Paper Association/American Wood Council, Washington, DC, 1997.

Applied Research Associates, Inc., *Florida Commission on Hurricane Loss Projection Methodology*, Florida Hurricane Commission, Tallahassee, FL, February 2001.

Arya, S.P.S., *Introduction to Micrometeorology*, Academic Press, 1988

ASCE 7-98, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, New York, NY, 2000.

ASTM E 1886-97, *Standard Test Method for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*, American Society for Testing and Materials, Philadelphia, PA, 1997.

ASTM E 1996-99, *Standard Specification for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Wind-borne Debris in Hurricanes,* American Society for Testing and Materials, Philadelphia, PA, 1999.

Bock, H.H., "On Some Significance Tests in Cluster Analysis," *Journal of Classification*, Vol. 2, pp. 77-108, 1985.

Case, P.C., "Wind Loads on Low Buildings with 4:12 Gable Roofs," M.S. Thesis, University of Western Ontario, London, Ontario, Canada, May 1996.

Chouinard, L.E, Liu Chang, and C.K. Cooper, "Model for Severity of Hurricanes in Gulf of Mexico", *Journal of Waterway, Port, Costal and Ocean Engineering*, Vol. 123, No. 3, pp. 120-129, 1997.

Darling, R.W.R., "Estimating Probabilities of Hurricane Wind Speeds Using a Large-Scale Empirical Model," *Journal of Climate*, Vol. 4, No. 10, pp. 1035-1046, 1991.

Emanuel, K.A., "The Maximum Intensity of Hurricanes", *Journal of the Atmospheric Sciences*, Vol. 45, pp. 1143-1155, 1988.

Everitt, B.S., "Unresolved Problems in Cluster Analysis," *Biometrics*, Vol. 35, pp. 169-181, 1979.

Everitt, B.S., *Cluster Analysis*, 2nd Edition, Heineman Educational Books Ltd., London, 1980.

FC&PA, *Guide to Concrete Masonry Residential Construction in High Wind Areas*, Florida Concrete & Products Association, Inc., Orlando, FL, 1997.

FEMA, *Building Performance: Hurricane Andrew in Florida*, Federal Emergency Management Agency, Federal Insurance Administration, FIA-22 (2/93), December 21, 1993.

Florida Building Code 2001, State of Florida, Tallahassee, FL, 2001.

Florida Department of Revenue (P.T.A.), *Standard N.A.L. (Name, Address, Label) File Record Layout, DR-590 (12D.8)*, Tallahassee, FL, 1995.

Florida Windstorm Underwriting Associates, *Manual of Rates, Rules, and Procedures*, Jacksonville, FL, July 2001.

Georgiou, P.N., "Design Windspeeds in Tropical Cyclone-Prone Regions," Ph.D. Thesis, Faculty of Engineering Science, University of Western Ontario, London, Ontario, Canada, 1985.

Hartigan, J.A., "Statistical Theory in Clustering," *Journal of Classification*, Vol. 2, pp. 63-76, 1985.

Ho, T.C.E., "Variability of Low Building Wind Loads," Ph.D. Thesis, Faculty of Engineering Science, University of Western Ontario, London, Ontario, Canada, 1992.

Jarvinen, B.R., C.J. Neumann, and M.A.S. Davis, "A Tropical Cyclone Data Tape for the North Atlantic Basin 1886-1983: Contents, Limitations and Uses," NOAA Tech. Memo. NWS NHC 22, U.S. Department of Commerce, Washington, DC, 1984.

Mehta, K.C. and R.D. Marshall, *Guide to the Use of the Wind Load Provisions of ASCE 7-95*, American Society of Civil Engineers, Reston, VA, 1998.

Powell, M.D., and S.H. Houston, "Hurricane Andrew's Landfall in South Florida – Part II: Surface Wind Fields and Potential Real-Time Applications," *Weather and Forecasting*, Vol. 11, No. 3, pp. 329-349, 1996.

Sarle, W.S., "Cluster Analysis by Least Squares," *Proceedings Seventh Annual SAS Users Group International Conference*, SAS Institute Inc., Cary, NC, pp.651-653, 1982.

SAS Institute Inc., *SAS/STAT User's Guide*, Version 6, 4th Edition, Volume 1, SAS Institute Inc., Cary, NC, 1992.

Shapiro, L.J., "The Asymmetric Boundary Layer Flow Under a Translating Hurricane," *Journal of Atmospheric Science,* Vol. 40, No. 8, pp. 1984-1998, 1983.

South Florida Building Code, 1984 Edition, Miami, Metropolitan Dade County, FL, 1984.

South Florida Building Code, 1994 Edition, Miami, Metropolitan Dade County, FL, 1994.

South Florida Building Code, 1999 Revisions, Miami, Metropolitan Dade County, FL, 1999.

SSTD 10-99, *SBCCI Standard for Hurricane Resistant Residential Construction*, Southern Building Code Congress International, Inc., Birmingham, AL, 1999.

SSTD 12-99, *SBCCI Test Standard for Determining Impact Resistance from Wind-borne Debris*, Southern Building Code Congress International, Inc., Birmingham, AL, 1999.

Standard Building Code 1997 Edition, Southern Building Code Congress International, Inc., Birmingham, AL, 1997.

Symons, M.J., “Clustering Criteria and Multivariate Normal Mixtures,” *Biometrics*, Vol. 37, pp. 35-43, 1981.

Twisdale, L.A., “A Risk-Based Design Against Tornado Missiles,” *Third ASCE Specialty Conference on Structural Design of Nuclear Plant Facilities*, Boston, MA, April 1979.

Twisdale, L.A., and P.J. Vickery, “Extreme Wind Risk Assessment,” Chapter 20, *Probabilistic Structural Mechanics Handbook*, Van Nostrund Reinhold, New York, 1995.

Twisdale, L.A., and P.J. Vickery, “Uncertainties in the Prediction of Hurricane Windspeeds,” *ASCE Conference on Hurricanes 1992*, Miami, FL, December 1993.

Twisdale, L.A., et al., “Tornado Missile Risk Analysis,” Volumes I and II, EPRI NP-769, Electric Power Research Institute, Palo Alto, CA, May 1978.

Twisdale, L.A., P.J. Vickery and J.-X. Lin, “Analysis of Hurricane Windborne Debris Impact Risk for Residential Structures: Part I,” to be submitted to the *ASCE Journal of Structural Engineering*, 2000a.

Twisdale, L.A., P.J. Vickery and J.-X. Lin, “Analysis of Hurricane Windborne Debris Impact Risk for Residential Structures: Part II,” to be submitted to the *ASCE Journal of Structural Engineering*, 2000b.

Twisdale, L.A., W.L. Dunn, et al., “Tornado Missile Simulation and Design Methodology,” Volumes I and II, EPRI NP-2005, Research Triangle Institute, Research Triangle Park, North Carolina, for Electric Power Research Institute, Palo Alto, CA, August 1981.

Vickery, P.J. and L.A. Twisdale, “Wind-Field and Filling Models for Hurricane Wind-Speed Predictions,” *Journal of Structural Engineering*, Vol. 121, No. 11, pp. 1700-1709, 1995a.

Vickery, P.J. and L.A. Twisdale, “Prediction of Hurricane Wind Speeds in The United States,” *Journal of Structural Engineering*, Vol. 121, No. 11, pp. 1691-1699, 1995b.

Vickery, P.J., J.-X. Lin, and L.A. Twisdale, “Analysis of Hurricane Windborne Debris Impact Risk for Residential Structures: Part II,” Final Rep. 5609, Rev. 1, Applied Research Associates, Inc., Raleigh, NC, April 1998.

Vickery, P.J., P.F. Skerlj, and L.A. Twisdale, “Simulation of Hurricane Risk in the United States Using an Empirical Storm Track Modeling Technique,” *Journal of Structural Engineering*, Vol. 126, No. 10, pp. 1222-1237, 2000.

Vickery, P.J., P.F. Skerlj, A.C. Steckley, and L.A. Twisdale, “Hurricane Wind Field Model for Use in Hurricane Simulations,” *Journal of Structural Engineering*, Vol. 126, No. 10, pp. 1203-1221, 2000.

WPPC, *Guide to Wood Construction in High Wind Areas*, Florida Wood Council, Orlando, FL, 1997.

APPENDIX A:

OVERVIEW OF ARA'S HURRICANE SIMULATION MODEL

APPENDIX A: OVERVIEW OF ARA'S HURRICANE SIMULATION MODEL

A.1 Introduction

The two key components that comprise ARA's hurricane simulation model in Hurloss 2.0 are (i) the hurricane wind field model and (ii) the overall hurricane climatological model. The wind field model provides information on windspeeds of a site given information on track, location, central pressure and size. The hurricane climate model provides the statistical (historical) information on occurrence rates, intensity distributions, storm size, etc used to model the risk at a location.

This appendix provides an overview of ARA's hurricane wind risk model described in detail in Vickery, et al. (2000a, 2000b).

A.2 Hurricane Wind Field Modeling

The hurricane wind field model contains two components. The first component is the overall mean flow field describing the upper level winds, and the second is the boundary layer model used to estimate windspeeds at the surface of the earth, given the upper level windspeeds

The mean flow field model solves the full nonlinear equations of motion of a translating hurricane and then parameterizes these solutions for use in fast running simulations. The use of a full numerical solution to the equations of motion for a hurricane allows the modeling of asymmetries in the storm that arise from the complex interaction of the frictional forces and the winds which vary throughout the storm. They can produce very high windspeeds wrapping around the eye wall in some small and intense storms. The use of simple empirical models to define the hurricane will not reproduce these effects.

The hurricane boundary layer model takes into account the effects of changing sea surface roughness and air-sea temperature difference on the estimated surface level wind. This allows for a more realistic representation of the windspeeds near the surface, and for better estimates of the effect of the sea-land interface in reducing windspeeds near the coast.

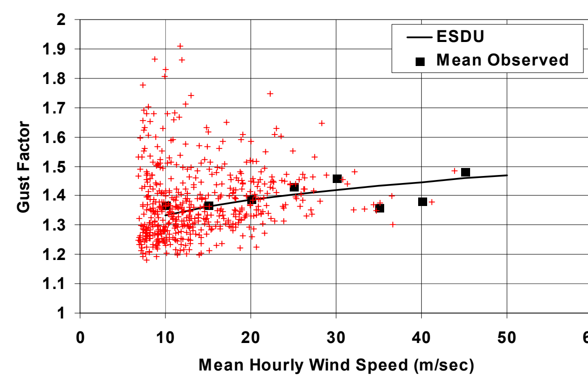
ARA has performed numerous comparisons between modeled and observed hurricane windspeed records. These include both comparisons of the ten-minute mean windspeeds and the peak gust windspeeds. The resulting wind field model is the most physically based and validated model currently in use for estimating hurricane windspeed exceedance probabilities.

Mean Wind Field Model. The wind field model is based on a dynamic numerical model of the planetary boundary layer (PBL). The model considers the equation of horizontal motion, vertically averaged over the height of the PBL. A finite difference scheme is used to solve for the steady-state wind field over a set of nested rectangular grids. These wind fields are then fit using a Fourier fitting approach so that each wind field can be described using a relatively small number of parameters. The equations are solved for 1560 combinations of central pressure, translation speed and radius to maximum winds for hurricanes both over land and over water. Parameterizing the solved wind field models enables us to retain the more accurate modeling associated with the numerical modeling of the hurricane while still enabling rapid storm simulations.

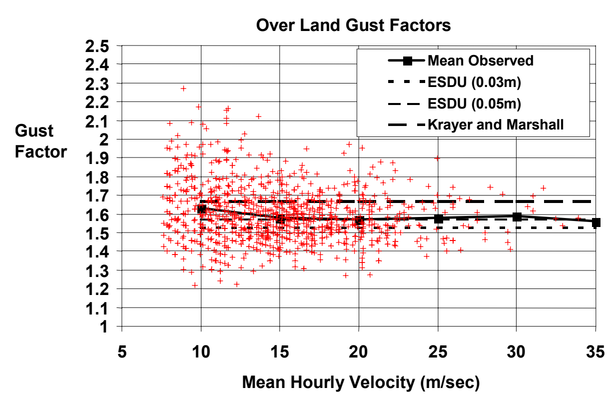
A similar approach for modeling hurricane wind fields resulting from a numerical solution to the equations of motion for a translating hurricane was first used by Georgiou (1985) and then by Vickery and Twisdale (1995a). In both of these studies the numerical model results were obtained from Shapiro's (1983) model, where the solutions to the equations of motion were themselves solved using a spectral approach employing the first two terms of the expansion. The approach used here has an advantage over the use of the Shapiro model, in that the full non-linear equations are solved, and then the results are fit to a Fourier series using more than two terms, hence maintaining a more precise solution to the equations of motion.

Boundary Layer Modeling. In all hurricane simulation procedures published to date, the hurricane boundary layer has been defined using empirical relationships between the upper level winds and the surface (10m) level winds. The ratio of the upper level winds to the surface level winds within these empirical models is very high (0.8-0.9) compared to typical values in extra-tropical storms (ratio of about 0.6 in open country terrain). The ratio of the surface level winds to the upper level winds within the hurricane is primarily a function of the air-sea temperature difference and the sea surface roughness, which is itself a function of windspeed. The hurricane wind field model described here uses a more theoretically based model of the hurricane boundary layer as described by Arya (1988). The hurricane boundary layer model yields ratios of the surface level windspeeds (at 10m) to the gradient level windspeeds, which vary as a function of the air-sea temperature difference and the mean windspeed at the surface. The ratio of the surface level windspeed divided by the upper level windspeed decreases with increasing windspeed. This decrease in the windspeed ratio is caused by the roughness of the sea surface increasing with windspeed. At very high windspeeds the ratio of the surface level to the upper level windspeeds approaches 0.6; and thus, for these very intense storms, the windspeeds over land are not reduced nearly as much as the over land windspeeds associated with the more common less intense storms, which agrees with the observations of Powell and Houston (1996).

Figure A-1 shows observed hurricane gust factors at a height of 10m vs. windspeed in comparison to modeled values of the gust factors. The gust factor models given in Fig. A-1 were originally developed for non-hurricane winds. The full scale (observed) gust factor data was derived using the full scale hurricane windspeed records given in Tables A-1 (marine stations) and A-2 (land-based stations). The increase in the gust factor with windspeed seen in the case of the marine gust factors is produced by the increase in the roughness of the sea surface with increasing wind speed.



(a) Over Water Gust Factors



(b) Over Land Gust Factors

Figure A-1. Comparisons of Observed and Model Gust Factors Over Water and Over Land

Table A-1. Comparison of Observed and Simulated Maximum Peak Gust Wind Speeds for Marine Stations Having Complete Continuous Records

Hurricane and Station	Measured Peak Gust at 10m (m/sec)	Anemom. Height (m)	Wind Speed Averaging Time (sec) Mean	Gust	Holland's *B* Parameter	Radius to Maximum Winds	Simulated Peak Gust Speed at 10m (m/sec)	Simulated Divided By Observed
Fran (1996)								
FPSN7	48.3,37.7	44.2	600	5	0.95	85	47.6,45.0	0.99,1.19
CLKN7	37.3	9.8	600	5	0.95	85	36.7	0.98
DSLN7	29.6	46.6	600	5	0.95	85	27.2	0.92
Bertha (1996)								
FPSN7	45.1	44.2	600	5	1.2	70	46.5	1.03
CLKN7	38.6	9.8	600	5	1.2	70-75	37.6	0.97
DSLN7	35.4	46.6	600	5	1.2	70-75	26.7	0.75
Emily (1993)								
DSLN7	51.0,56.7	46.6	600	5	1.7	39	59.4,56.2	1.16,0.99
Andrew (1992)								
MLRF1	29.9	15.8	600	5	1.6	19	36.4	1.22
NGW LMS	58.6	13.7	120	5	1.6	19	45.1	0.77
Bob (1991)								
DSLN7	47.6	46.6	600	5	1.4	35	51.4	1.08
CLKN7	24.1	9.8	600	5	1.4	35	20.9	0.87
41001	30.6	5.0	600	5	1.4	35	23.6	0.77
44008	31.3	13.8	600	5	0.8	55-70	32.0	1.02
Hugo (1989)								
FPSN7	31.7	44.2	600	5	1.0	40	29.7	0.94

The data given in Fig. A-1 for the land-based stations indicates that (considering the errors associated with the estimation of surface roughness on land, and the effects of trees, buildings and upstream terrain) the gust factor model performs well. There is no evidence to suggest, for strong winds, that the gust factors associated with hurricane winds are appreciably different from those associated with extra-tropical storm winds. The fact that the gust factor can be modeled using standard boundary layer theory is significant since it indicates that the turbulence and, hence, reductions in windspeed near the ground are produced by the local surface roughness. As a result we can reliably estimate the reductions in windspeed in suburban areas, provided a reasonable estimate of the surface roughness can be obtained.

Pressure Profile Modeling. A feature recently added to the HURSIM model is the incorporation of Holland's (1980) pressure profile parameter. The pressure deficit, Δp, at any distance from the center of the storm is defined as

$$\Delta p(r) = \Delta p_o \, e^{-(R_{max} / r)^B} \qquad \text{(A.1)}$$

where R_{max} is the radius to maximum winds, Δp_o is the central pressure deficit, r is the distance from the center of the storm, and B is the pressure profile parameter. The radial pressure profile parameter can have values ranging between about 0.5 and 2.5. The larger the value of B, the larger the windspeeds in the storm for the same Δp_o.

In real hurricanes Eqn. A.1 approximates the pressure field, but in many cases the value of B can vary along a single radial line. Using over 1,000 radial profiles of aircraft measurements of pressure and velocity obtained by NOAA, we produced estimates of an effective value of B through trial and error. Using this approach, we solve the gradient balance equations for a moving hurricane and minimize the error between the predicted windspeeds and observed upper level windspeeds by changing the value of B. Figure A-2 shows some examples of the B

Table A-2. Comparison of Observed and Simulated Maximum Peak Gust Wind Speeds for Land Based Stations Having Complete Continuous Records

Hurricane and Station	Measured Peak Gust at 10m (m/sec)	z_0 (m)	Anemom. Height (m)	Wind Speed Averaging Time (sec) Mean	Gust	Holland's B Parameter	Radius to Max. Winds (km)	Simulated Peak Gust at 10m (m/sec)	Simulated Divided by Observed
Fran (1996)									
Kure Beach	41.7	0.02	10	3600	3	0.95	85	46.0	1.10
Wilmington ASOS	39.2	0.05	10	600	5	0.95	85	43.1	1.10
Raleigh ASOS*	34.0	0.05	10	120	3	0.95	85	38.4	1.13
New River*	41.5	0.05	10	120	3	0.95	85	42.3	1.02
Greensboro Airport*	24.5	0.05	10	120	3	0.95	85	23.0	0.94
Cherry Point CF	34.6	0.10	10	600	5	0.95	85	34.7	1.00
Cherry Point R32	32.0	0.10	10	600	5	0.95	85	34.7	1.08
Seymour Johnson AFB*	41.4	0.05	4	120	3	0.95	85	41.8	1.01
Bertha (1996)									
Kure Beach	40.5	0.02	10	3600	3	1.2	70	41.9	1.03
Wilmington ASOS*	35.0	0.05	10	120	3	1.2	70	37.7	1.08
Seymour-Johnson AFB*	30.9	0.05	4	120	3	1.2	70-75	29.2	0.94
New River*	47.4	0.05	10	120	3	1.2	70-75	39.4	0.83
Beaufort Marine Lab.	37.7	0.03	7	3600	3	1.2	70-75	39.3	1.04
Opal (1995)									
Pensacola LLWSAS	30.2	0.2,0.03	12.2	600	3	0.9	30-40	41.7	1.38
Hurlbert Field*	54.3	0.01	3.5	120	3	0.9	30-40	59.5	1.10
Erin (1995)									
Pensacola LLWSAS	38.3	0.05,0.2	12.2	600	3	1.7	42	39.2	1.02
Hurlbert Field*	49.6	0.01	3.5	120	3	1.7	42	48.4	0.98
Bob (1991)									
Providence Airport	30.1	0.03	6.2	600	3	0.8	55-70	34.5	1.15
Logan Airport	30.8	0.03	5.9	600	3	0.8	55-70	32.7	1.06
Hugo (1989)									
Myrtle Beach AFB	40.5	0.03	3.0	900	3	1.0	40	37.1	0.92
Shaw AFB	55.0	0.05	4.6	900	3	1.0	40	54.8	1.00
Charleston Naval Station	48.1	0.20	36.0	900	3	1.0	40	47.2	0.98
Charlotte Airport	38.4	0.10	10.0	600	3	1.0	40	41.5	1.08
Columbia Airport	33.5	0.05	6.1	600	3	1.0	40	38.2	1.14
Elena (1985)									
Mobile Airport	28.2	0.05	6.7	600	3	1.55	22	33.2	1.18
Pensacola NAS	32.3	0.10	23.8	600	3	1.55	22	34.2	1.06
Pensacola Airport	30.4	0.05	6.7	600	3	1.55	22	30.6	1.01
Alicia (1983)									
Houston Airport	36.8	0.05	6.1	600	3	1.2	55	44.8	1.22
Alvin WSO	31.9	0.20	10.0	600	3	1.2	41-55	36.6	1.15
Galveston WSO	36.2	0.30	32.0	600	3	1.2	41-55	38.1	1.05
Dow Plant "A"	38.2	0.15	10.0	600	3	1.2	28-55	35.9	0.94
Frederic (1979)									
Ingalls Shipyard	50.4	0.05	10.0	600	3	1.3	38	52.0	1.03
Mobile Airport	45.2	0.05	6.7	600	3	1.3	38	49.0	1.08
Pensacola NAS	36.7	0.10	23.8	600	3	1.3	38	34.7	0.95
Pensacola Airport	36.7	0.05	6.7	600	3	1.3	38	33.1	0.90

values derived using Eqn. A.1 directly (top plot in each pair) and shows the upper level windspeeds resulting from the effective value of *B* (bottom plot in each pair). In the top plots the pressures are plotted in a transformed manner so that if Eqn. A.1 is valid, the data should appear as a straight line with constant slope.

Wind Field Model Validation. The hurricane wind field model has been validated through comparisons to full-scale hurricane windspeed records obtained from over 95 windspeed traces recorded during twelve hurricanes. Comparisons between simulated and observed windspeeds are performed separately for stations located inland, offshore, and at the coastline. Hurricanes are modeled using track information (position, central pressure) obtained from the National Hurricane Center, with information of radius to maximum winds from the Hurricane Research Division or

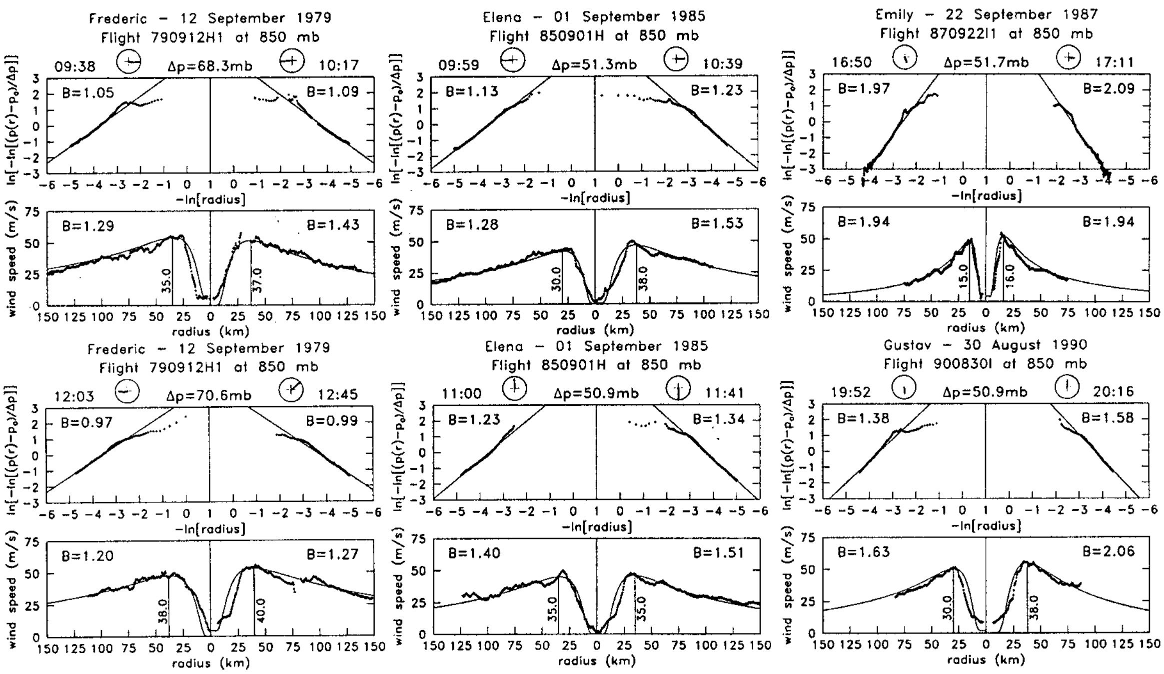


Figure A-2. Comparisons of Holland's B Parameter Derived from the Pressure and Velocity Fields

aircraft data. Figures A-3 through A-5 show comparisons of simulated and observed wind speeds for inland, marine, and coastal stations respectively.

The comparisons show good agreement between the simulated and observed wind speeds, particularly for the offshore and coastal stations. The agreement for the land-based stations is not as good. This is attributed to the errors associated with estimating the surface roughness length and the effects of upstream terrain, nearby trees, buildings, etc. The comparisons to the wind speeds measured offshore and near the coast are the best measures of the ability of the hurricane wind field model to reproduce the observed wind speeds since wind speeds measured at these stations are not affected by local terrain and roughness effects.

Summary. The analysis of the hurricane gusts factors indicates that on average the gust factors associated with hurricane winds do not differ from those associated with extra-tropical winds. Occasionally very large gust factors (>2) are observed; however, these generally occur at relatively low mean wind speeds. The boundary layer modeling has been improved over the models used in prior hurricane risk studies by taking into account the air-sea temperature difference, the change in the sea surface roughness with wind speed, and by using a physically based gust factor model that properly models the variation in the gust factor with surface roughness.

The modeling of the hurricane wind field has also been improved in comparison to models used in previous studies. It employs the full non-linear solution to the equations of motion of a hurricane (rather than the spectral model used in Georgiou (1985) or Vickery and Twisdale (1995a), or the empirical models used in all other studies). Evaluation of the hurricane model through comparisons with real hurricane wind speed data shows that the model provides a good representation of the hurricane wind field. The hurricane wind field model relies,

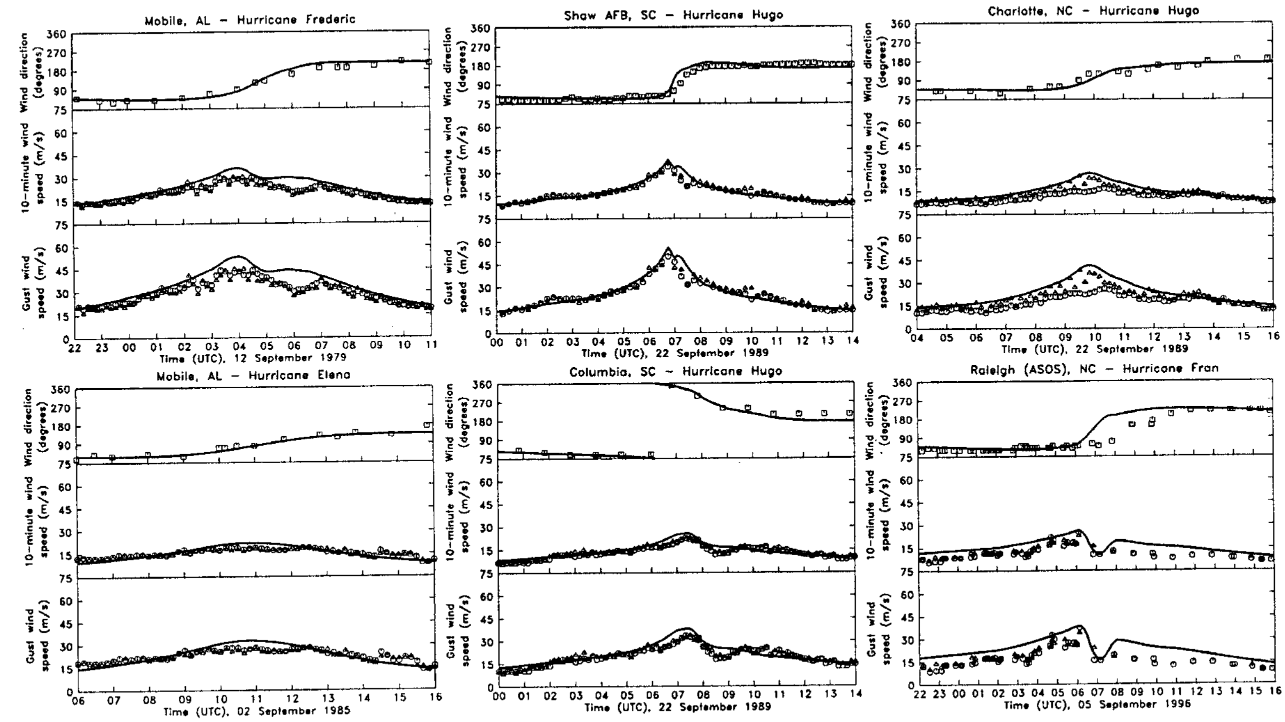


Figure A-3. Comparison of Observed and Modeled Hurricane Windspeeds at Inland Station

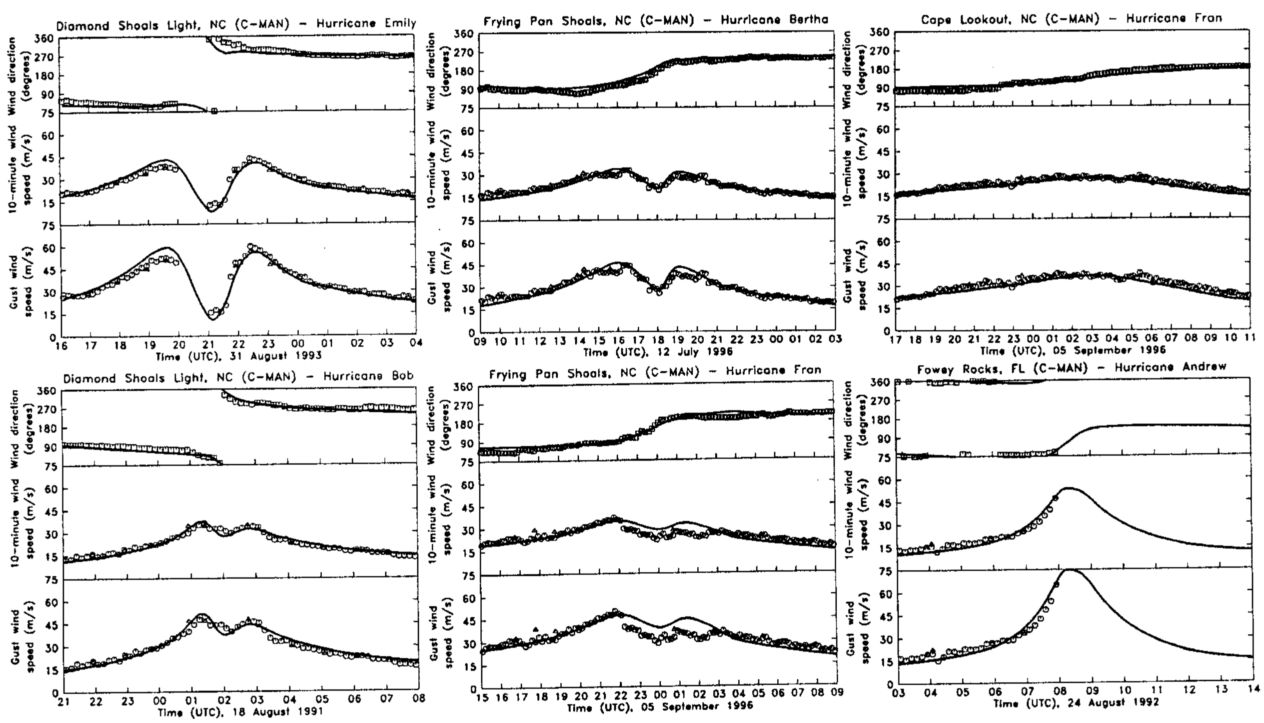


Figure A-4. Comparisons of Observed and Modeled Hurricane Windspeeds at Marine Stations

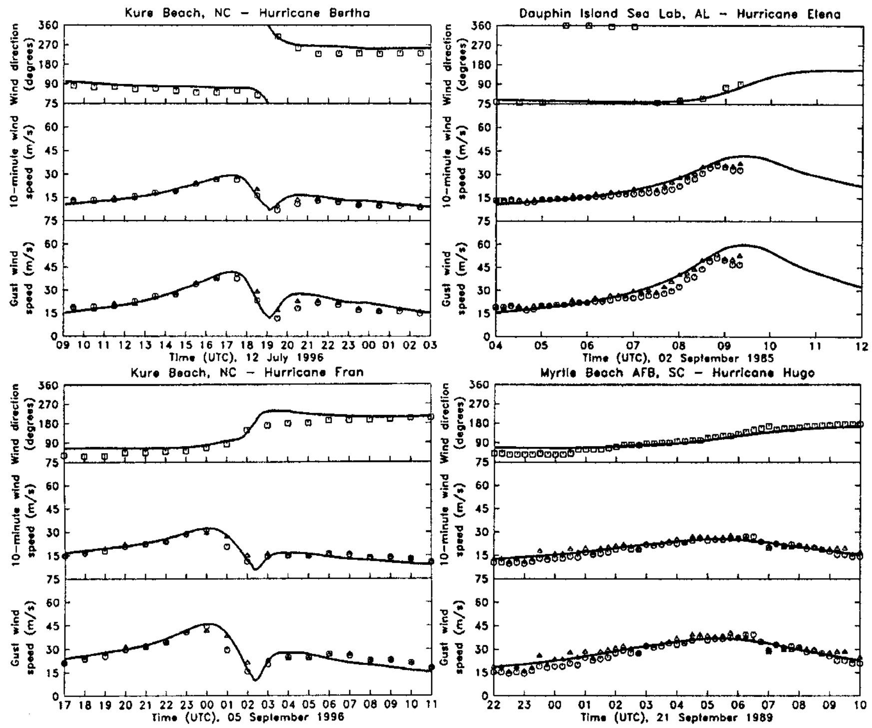


Figure A-5. Comparisons of Observed and Modeled Hurricane Windspeeds at Coastal Stations

wherever possible, on physical models rather than empirical models to describe the wind speeds within the storm, and is the most advanced hurricane model currently in use for estimating hurricane wind speed risk.

A.3 Climatological Modeling

ARA's storm track model simulates, the number of storms in an ocean basin in any one year by sampling from a negative binomial distribution. The starting position, date, time, initial heading, and initial translation speed are sampled from the historical data of all tropical storms in the HURDAT databases. Using the historical starting positions of the storms (i.e., date and location) ensures that the climatology associated with any seasonal preferences for the point of storm initiation is retained. Given the initial storm heading, speed and intensity, the simulation model estimates the new position and speed of the storm based on the changes in the translation speed and storm heading over the current six-hour period. The changes in the translation speed, c, and storm heading, θ, between times i and i+1 are obtained from

$$\Delta\, ln\, c = a_1 + a_2\psi + a_3\lambda + a_4\, ln\, c_i + a_5\theta_i + \varepsilon \qquad \text{(A.2a)}$$

$$\Delta\theta = b_1 + b_2\psi + b_3\lambda + b_4 c_i + b_5\theta_i + b_6\theta_{i-1} + \varepsilon \qquad \text{(A.2b)}$$

where a_1, a_2, etc., are constants, ψ and λ are the storm latitude and longitude, respectively, c_i is the storm translation speed at time step i, θ_i is the storm heading at time step i, θ_{i-1} is the heading of the storm at time step i-1, and ε is a random error term. The coefficients a_1, a_2, etc., have been developed using 5-degree by 5-degree grids over the entire ocean basin. A different set of coefficients for easterly and westerly headed storms is used. As the simulated storm moves into a different 5-degree by 5-degree square, the coefficients used to define the changes in heading and speed change accordingly.

The central pressure of a storm is modeled through the use of a relative intensity parameter which is coupled to the sea surface temperature. Modeling hurricanes using this relative intensity concept was first used in single point simulations by Darling (1991). Note that while the actual central pressure of a hurricane is a function of more than the sea surface temperature (i.e., wind shear aloft, storm age, depth of warm water, etc.), the modeling approach is an improvement over traditional simulation techniques in that the derived central pressures are bounded by physical constraints, thus eliminating the need to artificially truncate the central pressure distribution.

The relative intensity approach is based on the efficiency of a tropical cyclone relative to a Carnot cycle heat engine and the details of the approach given in Darling (1991). To compute the relative intensity, *I,* of a hurricane, we use the mean monthly sea surface temperatures in the ocean basin (given in one-degree squares) at the location of the storm, combined with the central pressure data given in the HURDAT data base (see description in Jarvinen, et al., 1984), an assumed relative humidity of 0.75, and a temperature at the top of the stratosphere taken to be equal to 203^{o} K (Emanuel, 1988). Using the approach given in Darling (1991), every central pressure measurement given in HURDAT is converted to a relative intensity.

During the hurricane simulation process, the relative intensities, *I*, at each time step are obtained from,

$$\begin{aligned}(I_{i+1}) = c_0 + c_1 ln(I_i) + c_2 ln(I_{i-1}) + \\ c_3 ln(I_{i-2}) + c_4 T_s + c_5 (T_{s_{i+1}} - T_{s_i}) + \varepsilon\end{aligned} \qquad \text{(A.3)}$$

The coefficients c_0, c_1, etc., vary with storm latitude, storm intensity, basin (i.e., Gulf of Mexico, Atlantic Ocean or Pacific Ocean), and heading (i.e., Easterly or Westerly direction). Near the US coastline, where more continuous pressure data is available, finer, regionally specific values of these coefficients are developed. These regionally specific coefficients take into account changes in the relationships between sea surface temperature and storm intensity that may be influenced by subsurface water temperatures as described, for example, in Chouinard, et al. (1997). These regional coefficients preserve the variations in local hurricane climatology along the coastline, and through small adjustments in the coefficients, the model can be calibrated to match historical landfall rates of hurricanes. In the modeling process, once a simulated storm makes landfall, the reduction in central pressure with time is modeled using the filling models described in Vickery and Twisdale (1995a). If a storm moves back over water, Eqn. A.3 is again used to model the variation in central pressure with time.

Summary. The two hurricane modeling components, wind field and climatology, are combined together to estimate the windspeed risk at any site. The hurricane wind field model is the most extensively validated model ever used for hurricane wind risk estimation. The integrated model was used to develop the design windspeeds given in ASCE-7-98 and ASCE-7-01, as well as forming the basis of the hurricane risk model in HAZUS. The hurricane model has been extensive reviewed through the ASCE-7 Task Committee on Wind Loads, HAZUS Wind Committee, and Florida Commission on Hurricane Loss Projection Methodology. It has been used to develop design criteria for buildings to be constructed in the United States, Japan, the Caribbean, China, Hong Kong, and Taiwan.

APPENDIX B:

OVERVIEW OF ARA'S LOAD, RESISTANCE, DAMAGE AND LOSS MODELS

APPENDIX B: OVERVIEW OF ARA'S LOAD, RESISTANCE, DAMAGE AND LOSS MODELS

B.1 Introduction

This appendix provides background of the overall building modeling approach used by ARA on this study. The HURLOSS methodology described herein uses a load and resistive based approach for estimating damage and loss to structures. Appendix A reviews the hurricane track and wind field modeling components of HURLOSS.

The key model components for building damage and loss are (i) the estimation of wind loads acting on a building, (ii) the estimation of debris impact probability, (iii) modeling of damage given the wind loads or debris impact, and finally, (iv) the prediction of losses given damage. Each of these key components are discussed in the following sections, along with model validation examples.

Model validations are given for wind loads, wind damage and loss estimation. The load-resistance-damage-loss methodology described in this appendix provides the framework needed to reliably examine the effect of mitigation in a quantitative manner. Since the model reproduces the physics of wind damage and loss, we can change the resistance of various components and see what effect these changes have on the resulting damage.

HURLOSS has been reviewed and accepted by the Florida Commission on Hurricane Loss Modeling for the 1999 and 2000 Standards. HURLOSS will be submitted again in February 2002 for the 2001 Standards.

B.2 Wind Pressures

The first step in the estimation of damage should involve estimates of wind loads acting on the structure. Without this critical step it is not possible to reliably address mitigation concepts or estimate the true capacities of building components. The reliable estimation of wind loads acting on buildings is the key to developing damage models that can address construction quality, the effect of building component performance, mitigation issues and building upgrades. When coupled with estimates of building resistance the approach allows a framework to estimate the performance of buildings well beyond the original design load considerations. ARA has developed an empirical modeling approach to estimate the directionally dependent wind-induced pressures acting on the exterior of buildings during wind storms. The methodology used by ARA to estimate wind loads on buildings of various geometry's draws on a large number of boundary wind tunnel test results as well as ARA personnel's experience in boundary layer wind tunnel tests and the interpretation of test results.

The pressure coefficient loading models have been developed for sloped roof buildings, low rise flat roof buildings and mid to high-rise buildings. Figures B-1 through B-9 show some example comparisons of the simulated and wind tunnel modeled peak negative pressures acting on the exterior of some typical residential type buildings.

Figures B-1 through B-4 show example comparisons of pressures acting on the exterior of a flat roof building. The empirical pressure model for flat roof buildings uses a continuous function which estimates the wind-induced pressures as a function of a non-dimensional distance from the separation edge and any exterior corners. Figures B-5 through B-9 show example comparisons of pressures acting on the roofs of sloped roof buildings.

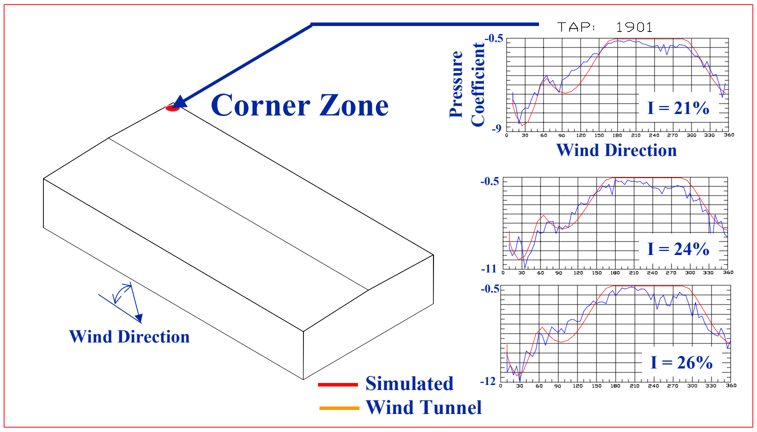


Figure B-1. Aerodynamic Load Validation Flat Roof - Corner Zone

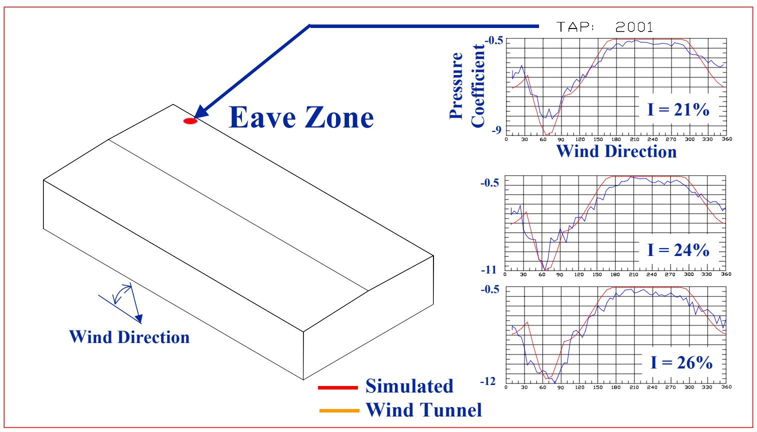


Figure B-2. Aerodynamic Load Validation Flat Roof - Eave Zone

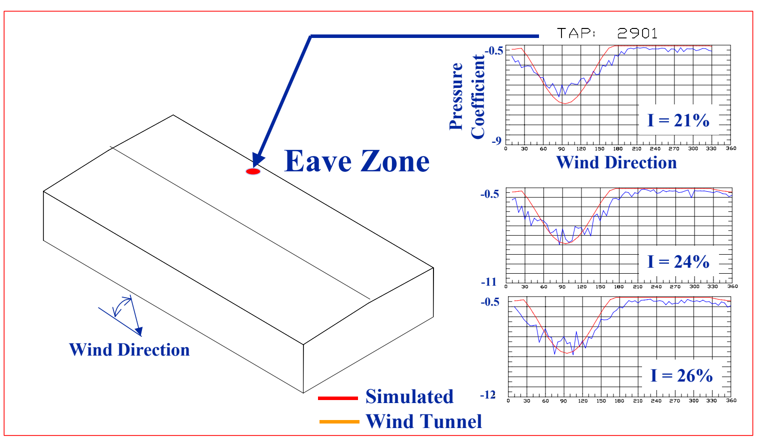


Figure B-3. Aerodynamic Load Validation Flat Roof - Eave Zone

Once the baseline pressures on the building are produced for an isolated building, the pressures are modified in damage simulations using the work of Ho (1992) and Case (1996).

The reduction in wind loads caused by the shielding and interference effects of surrounding buildings is applied in addition to the reduction in loads associated with the change in terrain from open country to suburban.

The individual modeled pressures are also used to define the overall uplift forces acting on the entire roof of a buildings, as well as for estimating overturning moments, and shear forces, which act to push unsecured buildings off their foundations. The model has been validated using wind tunnel test data for several complex building shapes tested in different boundary layer flow regimes. Wind loading coefficients have been generated for a wide range of building shapes and sizes, typical of those associated with residential buildings.

B.3 Wind-Borne Debris

Wind-borne debris is a major contributor to damage in high wind events, and reasonable modeling of the wind-borne debris is critical to the overall success of a physically based loss model. ARA has developed a first principle model for estimating hurricane debris impact probabilities, impact momenta and impact energy (Twisdale, Vickery and Steckley, 1996). The model is based on the TORMIS (TORnado MISsile) methodology developed by Twisdale et al. (1978, 1979, 1981).

The HURricane MISsile (HURMIS) methodology is used to assess window damage probabilities for buildings located in within

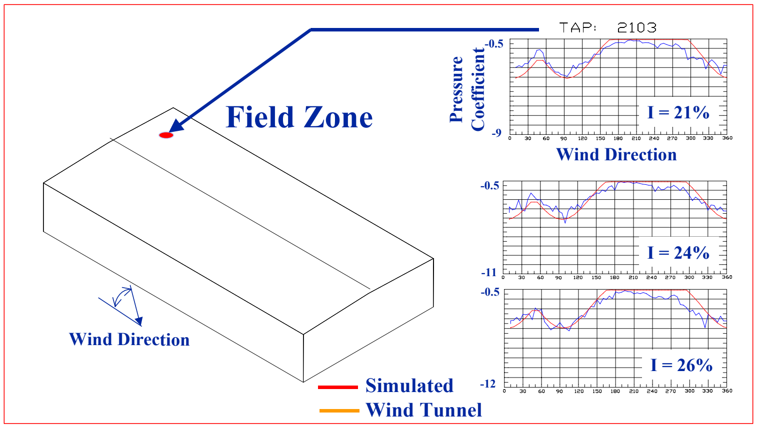


Figure B-4. Aerodynamic Load Validation Flat Roof - Field Zone

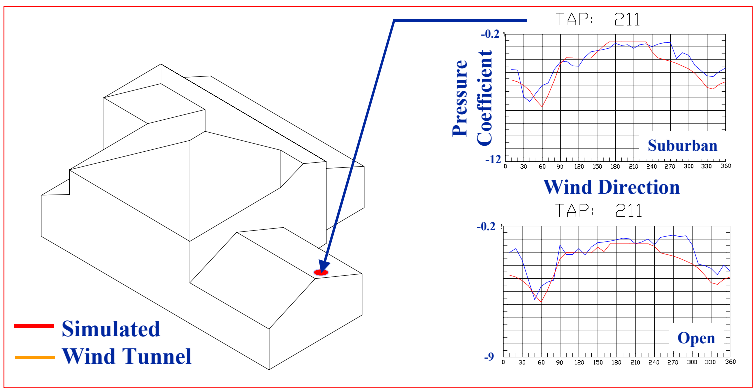


Figure B-5. Aerodynamic Load Validation Complex Geometry

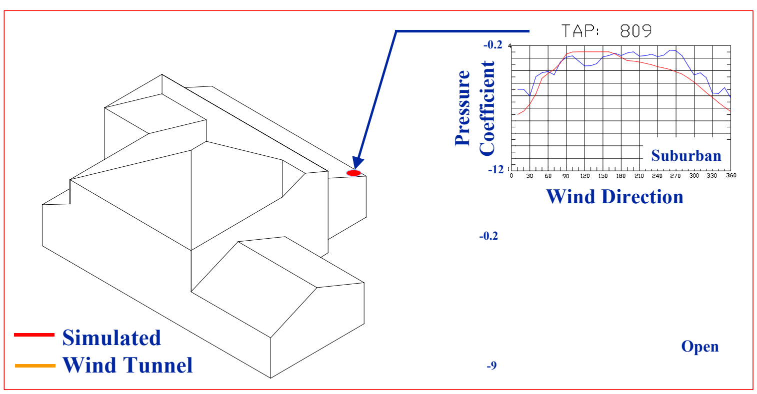


Figure B-6. Aerodynamic Load Validation Complex Geometry

different terrain's, building densities, missile source environments, etc. The methodology is outlined in Fig. B-10. Using the wind pressure model, coupled with component resistance models, we simulate the failure of individual components and track their trajectories in a turbulent hurricane boundary layer model. The HURMIS code is run offline to develop wind speed related impact probability distributions for ranges of terrain class, etc. that are then used in end-to-end damage simulations. Since information on impact velocities, momenta, energy, etc. are known, we can assess the effect of window protection on reduction in damage and loss. The HURMIS model is used explicitly in damage modeling directly, but has been used in the generation of energy and momentum risk curves that are used in conjunction with the wind loading models to develop building damage predictions as a function of wind speed.

The wind-borne debris modeled in HURMIS currently includes roof sheathing, roof trusses, roof tiles, roof shingles, whole roofs and roof canopies or overhangs, and failed sheds. The single largest contributor of damaging missiles are generated from the roofs of buildings.

During the development of the HURMIS model, ARA engineers collected information on missile transport distances following Hurricane Erin (1995) to validate the transport model. In the case of roof sheathing, four examples of failed roof sheathing were used for comparisons of simulated and observed sheathing transport. All the observed data was obtained from the Hurricane Erin damage survey performed at Navarre Beach. Photographs of the debris, schematic representations of the trajectories, and trajectory statistics for 2 of the 4 cases examined are shown in Figs. B-11 and B-12. A total of 19 trajectories were used in the

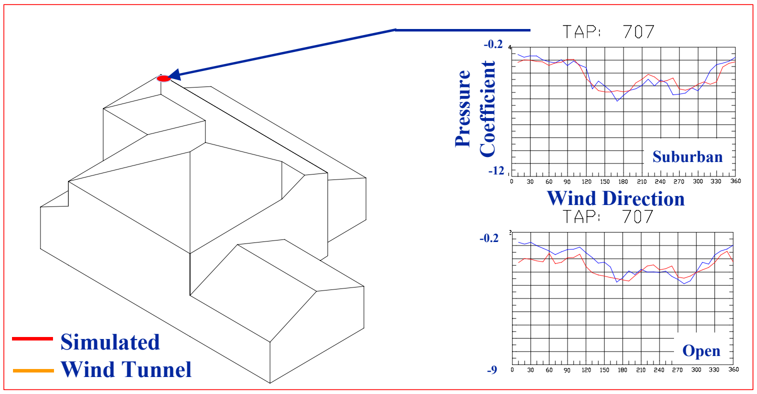


Figure B-7. Aerodynamic Load Validation Complex Geometry

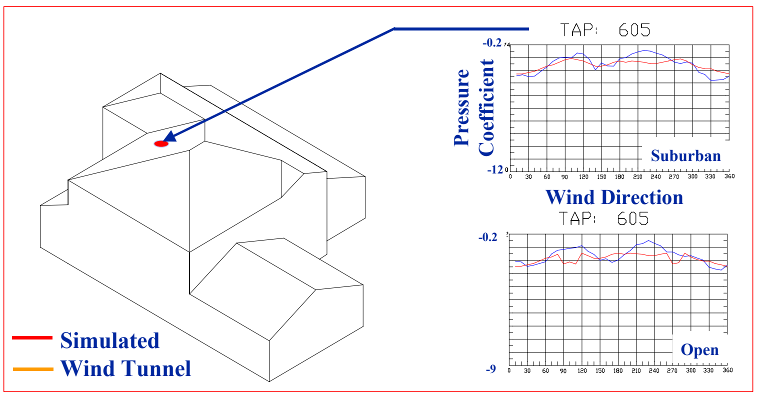


Figure B-8. Aerodynamic Load Validation Complex Geometry

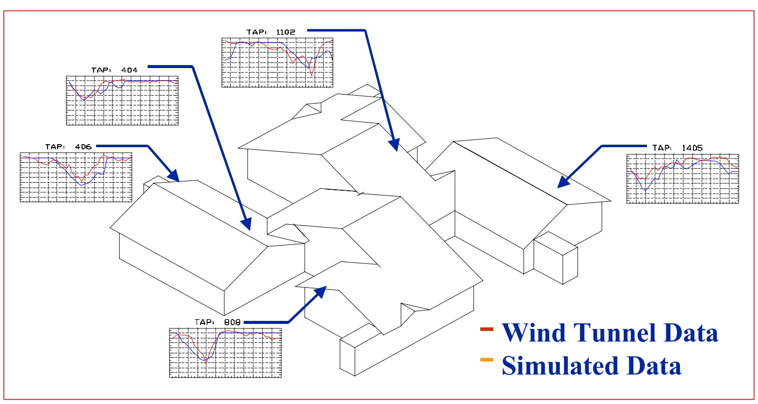


Figure B-9. Aerodynamic Load Validation Complex Geometry

comparisons. In order to simulate the sheathing trajectories, the HURSIM model was first used to produce a trace of simulated wind speeds and direction at Navarre Beach resulting from Hurricane Erin. Using the start and end positions of the observed missile transports combined with the simulated wind direction vs. time trace, the estimated time of failure for each piece of sheathing was obtained. In the simulation method each piece of sheathing is released into the wind field near the estimated failure time and flown until the missile strikes the ground. The simulation used the actual weights and dimensions of the sheathing as recorded in the debris survey. Each single piece of sheathing is simulated 10 times, resulting in a total of 190 simulated trajectories. Table B-1 summarizes the results on a case by case basis and with an aggregated case.

The comparisons given in Table B-1 show that on a case-by-case basis the percentage difference between mean simulated sheathing transport and the observed transport ranges between -48% and 62%, but on an aggregated basis the difference in the mean transport distance is negligible, although the simulated rms transport overestimates the observed rms transport. The maximum simulated transports are significantly larger than the observed transports because there are 10 times the number of simulated transports as compared to observed transports. The 90th and 95th percentiles of the simulated sheathing transports are 160 ft. and 207 ft., respectively, which bracket the observed overall maximum transport of 200 ft. Validations were also performed for roof tile transport and roof framing member transport.

Figure B-13 shows an example of a modeled subdivision used in the detailed study of missile impact probabilities. Also given in Fig. B-13 are example reliability curves that

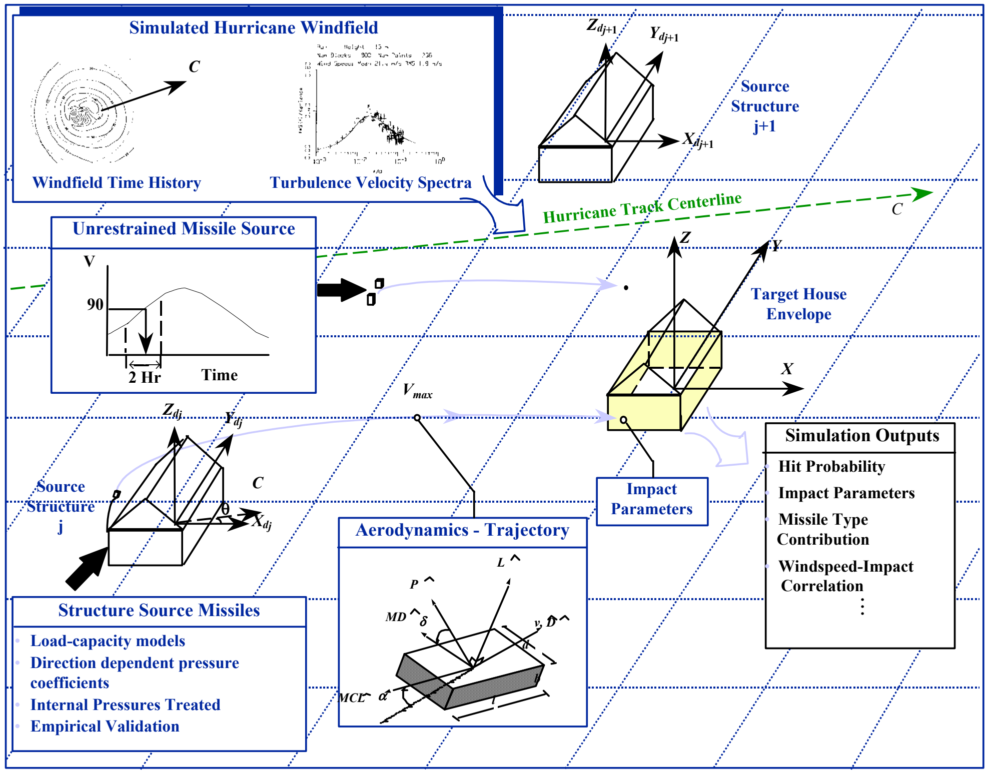


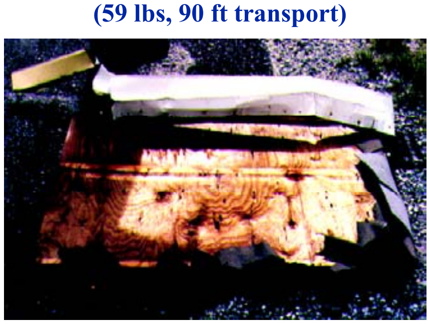
Figure B-10. ARA developed the HURMIS methodology to quantify the risk of wind-borne debris for individual buildings as well as for use in building and portfolio category loss assessment.

Source (95E-2-33)

Missile Characteristics

Missile	Type	Dimensions (in.)	Weight (lbs.)	Transport (ft.)
1	Ply-Shingles	48 x 42 x 0.5	59	90
2	Ply-Shingles	78 x 48 x 0.5	92	25
3	Ply-Shingles	48 x 42 x 0.5	65	10

Missile 1 (95E-2-34)
(59 lbs, 90 ft transport)



Transport Summary

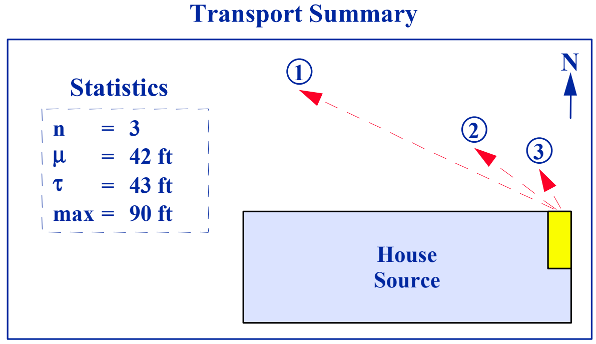


Figure B-11. Sheathing Transport Data for Case 1

Source (95E-4-12)

Missile Characteristics

Missile	Type	Dimensions (in.)	Weight (lbs.)	Transport (ft.)
1	Ply-Shingles	60 x 48 x 0.5	72	41
2	Ply-Shingles	96 x 48 x 0.5	98	87
3	Ply-Shingles	70 x 48 x 0.5	84	73
4	Ply-Shingles	84 x 33 x 0.5	69	120

Missile 3 (95E-4-8)
(84 lbs, 73 ft transport)

Transport Summary

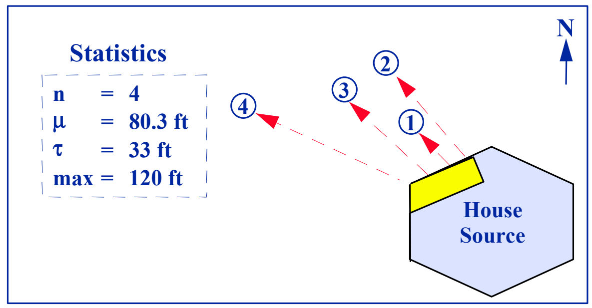


Figure B-12. Sheathing Transport Data for Case 2

Table B-1. Comparison of Simulated and Observed Sheathing Transport Data

Case	Number of Missiles	Observed Transport (ft)			Simulated Transport (ft)		
		Mean	RMS	Max.	Mean	RMS	Max.
1	3	42	42	90	68	58	240
2	4	80	33	120	113	89	400
3	4	130	81	200	68	73	330
4	8	68	26	91	72	81	508
Combined	19	79	50	200	80	80	508

provide information on the probability of windows being impacted by debris with a given energy level as a function of wind speed. Impact probability curves, derived from the HURMIS studies are used in HURLOSS to estimate the likelihood of missile impact damage to windows, doors, etc., during each simulated hurricane.

B.4 Building Component Resistance Modeling

Component resistances used in the load-resistance based model are based on a combination of engineering analyses and laboratory tests. Components that are damaged in the model include roof cover (shingles, tiles, built-up roof), roof sheathing (plywood, OSB and metal), windows (using both pressure failures and missile impact criteria), opening protection devices (both pressure and impact criteria), sliding glass doors, garage doors, and double and single entry doors. Roof uplift resistance is modeled using information from laboratory tests on toe-nail connections and a wide range of hurricane straps. The failure of wood and masonry walls are modeled using the results of first principles engineering analyses.

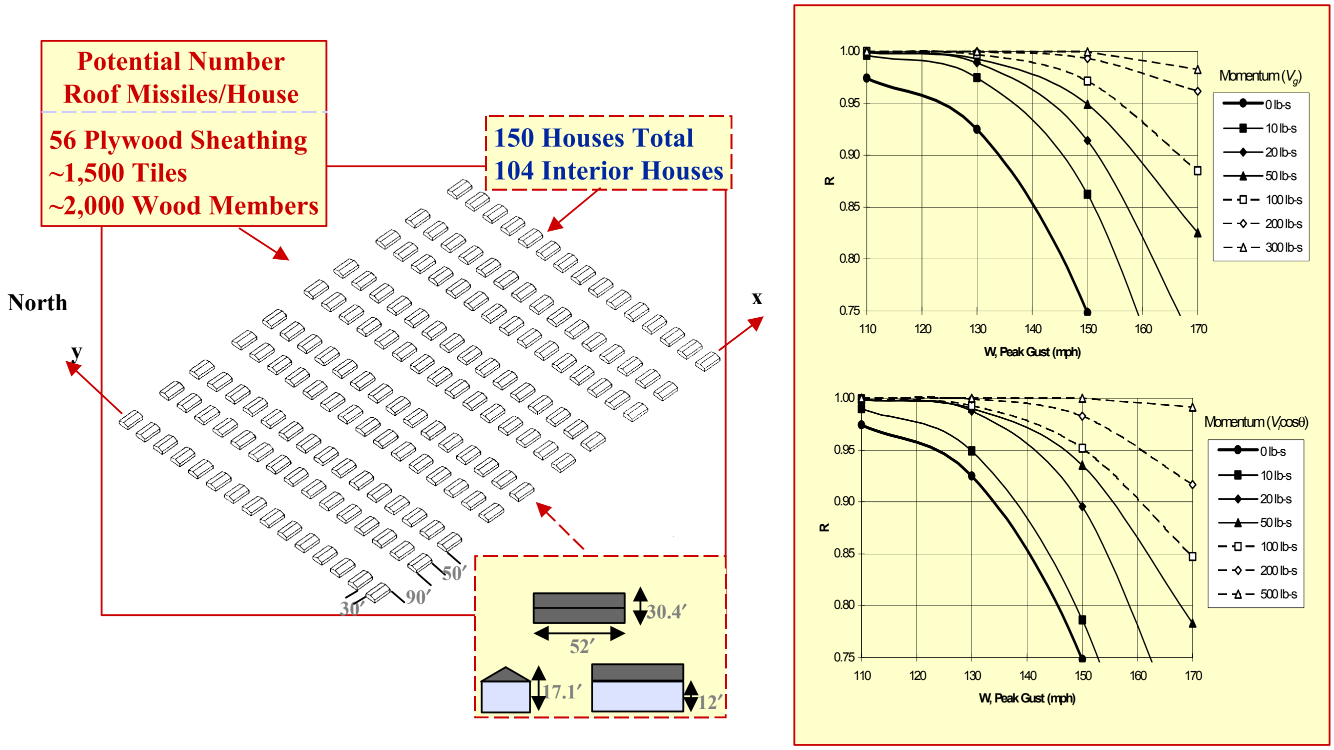
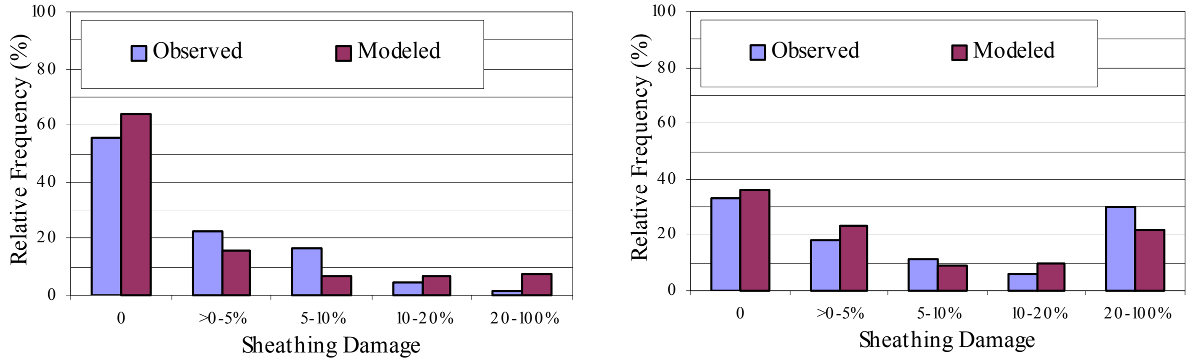


Figure B-13. Wind-Borne Debris Study Example Results for the subdivision indicated. Graphs show the required momentum or energy the windows must resist to ensure a given level of reliability, R.

Through the combination of individual site-specific hurricane simulations yielding estimates of wind speed and direction, coupled with the geometric representation of the buildings and the modeled building component resistances, the load-resistance-damage model can be validated, through comparisons with post storm damage data. We have performed damage validation studies by comparing model results to damage collected following Hurricanes Andrew, Erin, Fran, Bertha and Bonnie.

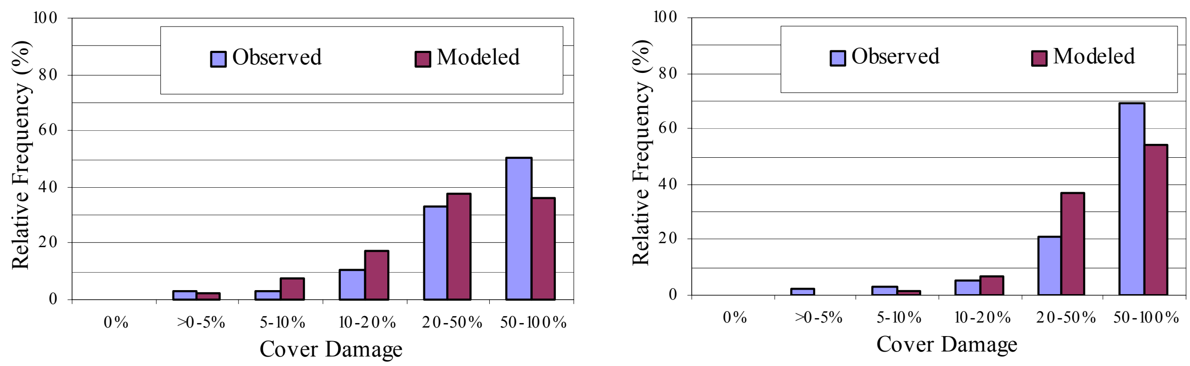
Figure B-14 presents a comparison of the observed and modeled damage to the roof sheathing of hip and gable roof homes following Hurricane Andrew. The observed sheathing damage was obtained from aerial photographs taken immediately following the landfall of Hurricane Andrew in South Florida. Note that for buildings with non-zero roof sheathing damage the estimates of the percentage of missing sheathing is visually estimated and thus is somewhat subjective. In the modeling of the damage to roof sheathing, since the information on the method of sheathing attachment is not known, the houses have been modeled with the roof sheathing attachment type distributed in accordance with information collected during inspections of residential structures in South Florida. The comparisons indicate that the overall agreement between the observed and modeled damage is reasonable with the model reproducing the fact that the gable roof homes experience significantly more roof sheathing damage than the hip roof homes.

Figure B-15 presents a comparison of the modeled and observed roof cover damage to hip and gable roof homes following Hurricane Andrew. Again, the observed data was obtained from the analysis of aerial



(a) Hip Roof Homes **(b) Gable Roof Homes**

Figure B-14. Comparison of Observed and Modeled Fraction of Homes with the Indicated % of Missing Roof Sheathing – Hurricane Andrew (Observed Data from Aerial Photography)



(a) Hip Roof Homes **(b) Gable Roof Homes**

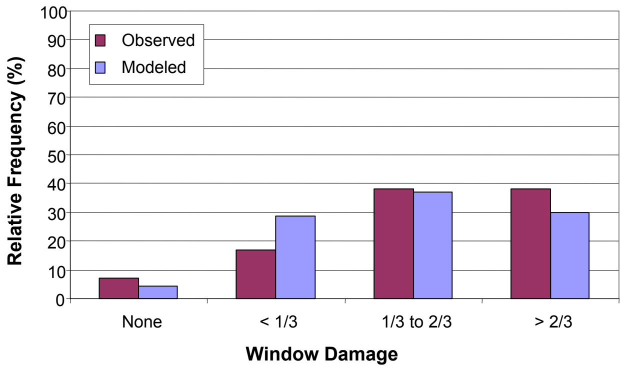
Figure B-15. Comparison of Observed and Modeled Fraction of Homes with the Indicated % of Missing Roof Cover – Hurricane Andrew (Observed Data from Aerial Photography)

photographs taken immediately following the landfall of the storm. As in the case of the roof sheathing damage comparisons, the estimates of the amount of roof cover loss is somewhat subjective, but the comparisons are generally good with the both the observed and modeled roof cover damage being higher on the gable roof homes compared to the hip roof homes.

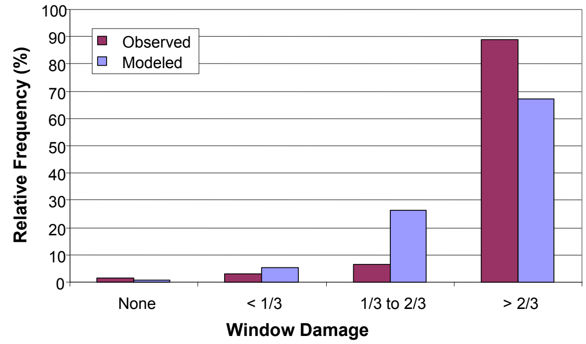
Figure B-16 presents a comparison of the modeled and observed fraction of homes with the indicated window damage state for both one story homes and two story homes. The observed window damage data is taken from the damage survey performed by NAHB following hurricane Andrew. The damage model reproduces the observation that the two story homes experienced significantly more window damage than did the one story homes, but the model tends to underestimate the fraction of two story homes having over two thirds of the windows broken.

B.5 Loss Modeling

The loss model developed by ARA was developed using information gathered from a combination of post storm investigations carried out by ARA engineers, as well as



(a) Single Story Homes



(b) Two Story Homes

Figure B-16. Comparison of Observed and Modeled Number of Homes with the Indicated Fraction of Broken Windows (Hurricane Andrew, Observed Data from HUD, 1993)

insurance loss data. The model estimates the financial damage (or losses) separately for the building, the contents, additional living expenses, and appurtenant structures. As described in the following sub-sections loss estimates are produced as a function of the physical damage to the building including damage to the building structure, and most importantly damage to the building envelope, which allows both or either rain and wind to enter the building causing damage to the interior of the building (interior walls, carpets, utilities, etc.) and damage to the contents of the building. The model has been validated both on a building-by-building basis and on an end-to-end basis through comparisons with insurance loss data on a storm-by-storm basis.

Building Loss Modeling. The financial losses sustained by the building are produced through the use of a cost estimation model that makes use of the prediction of physical damage to the building. The model produces separate estimates of losses associated with damage to the exterior of the building (associated with, for example, replacing roof cover, roof sheathing, damaged windows and doors, repairs to walls associated with missile impacts, or pressure failures, etc.) and damage to the interior of the building caused primarily from wind and water entering the building once the envelope has been breached.

Figure B-17 shows a comparison of the loss associated with damage to buildings plotted vs. the peak gust wind speed in open terrain. The active data are zip code aggregate losses and the modeled losses are estimates losses for that event using building stock models representative of that location.

Content Loss Modeling The content loss model used to estimate the vulnerability of contents is based on the physical damage, and the resulting possibility of wind and water entering the building following damage. Thus, while the damage to contents is a function of the damage to the building, the model is constructed in such a way that damage to contents does not occur until sufficient physical damage to the building has occurred to allow wind and/or water to enter the building causing damage to the contents. The content model has been validated/calibrated separately from the building vulnerability model. A comparison of modeled and observed content damage ratios as a function of the building loss are given in Fig. B-18, showing the suitability of the model for reproducing content losses given building losses.

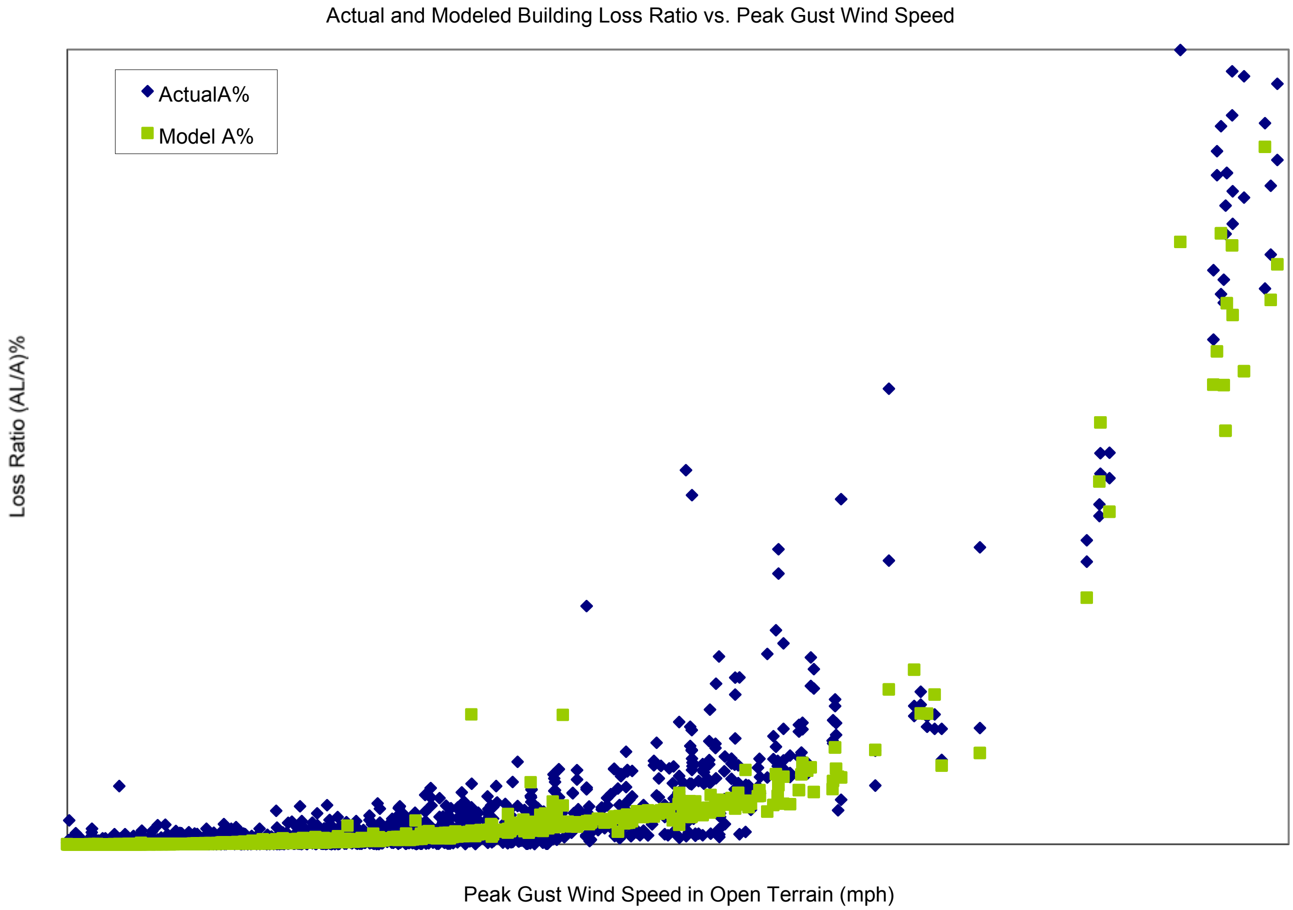


Figure B-17. Comparison of Modeled and Observed Building Losses vs. Peak Gust Wind Speed

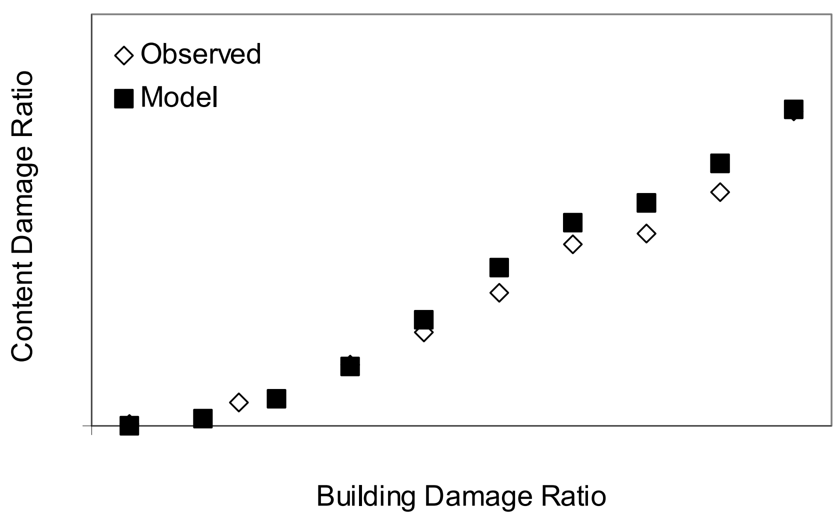


Figure B-18. Modeled and Observed Content Damage Ratio vs. Building Damage Ratio

Additional Living Expenses Additional living expenses are estimated using a model which estimates the time required to rebuild a damage structure and includes a component for damage to infrastructure due to storm surge and waves. The model does not initiate the computation for additional living expenses associated with wind-induced damage until the physical damage sustained to the building is significant enough such that the building is unlivable. ALE losses associated with storm surge and wave damage to the infrastructure can occur when there is no damage to the structure. Figure B-19 shows a zip-code level comparison of modeled and actual ALE costs.

Total Losses. Figure B-20 shows a comparison of the modeled and observed total loss (expressed as a ratio of the total insured value) as a function of peak gust wind speed in open terrain. Figure B-21 presents a comparison of modeled and reported insured losses on a storm-by-storm, company-by-company basis. The data given in Fig. B-21 contains insurance loss data from a number of companies for nine different hurricane events.

B.6 Individual Building Loss Analysis Methodology

As indicated in previous sections, ARA has developed a load-resistance-damage-and loss methodology that has been validated at both the damage level and the loss level. Damage validation studies have been performed through comparisons of observed comparing modeled and observed roof cover failures, roof sheathing failures, roof-wall connection failures, and window failures.

Given information on the damage to a building, loss models have been developed that estimate the financial damage to the building. The model separately estimates damage to the exterior of the building (windows, roof cover, roof sheathing, walls, roof-wall connections, etc.) and estimates of the replacement costs for these components are obtained. Subsequent damage to the interior of the building, including damage to contents is estimated using models developed from insurance data.

On a building-by-building basis, a direct simulation approach is used to develop estimates of average annual loss. Using this approach, an *N* year simulation of hurricanes is performed, with the damage and loss computed for each storm that impacts the building. At the completion of the simulation, a synthesized *N* year simulation of loss history has been developed, from which the average annual loss is readily determined by summing the losses and dividing by the number of years in the simulation. The simulation methodology takes into account the effect of storm duration and changes in wind direction during the storm, since wind loads are computed at discrete time intervals during the passage of the storm.

Mitigation Analysis Example. Since the damage and loss models are constructed with this load and resistance modeling approach, it is possible to estimate the reduction in losses associated with the application of a mitigation technique (such as improving roof-wall connections). The modeling methodology has been used for the past several years in the Residential Construction Mitigation Program (RCMP) in Florida. Figure B-22 shows an example of the expected losses to a building before and after mitigation plotted vs. storm intensity (as defined by wind speeds at the location of the building).

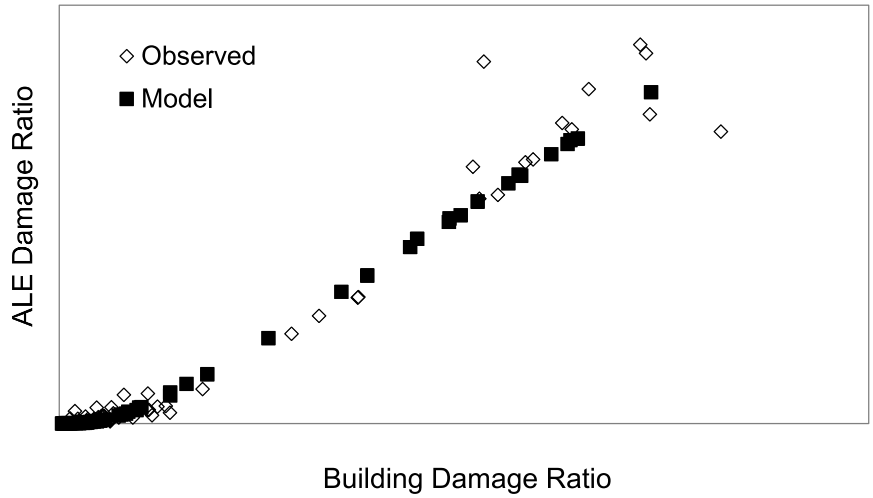


Figure B-19. Comparison of Modeled and Observed Mean ALE Damage vs. Mean Building Damage

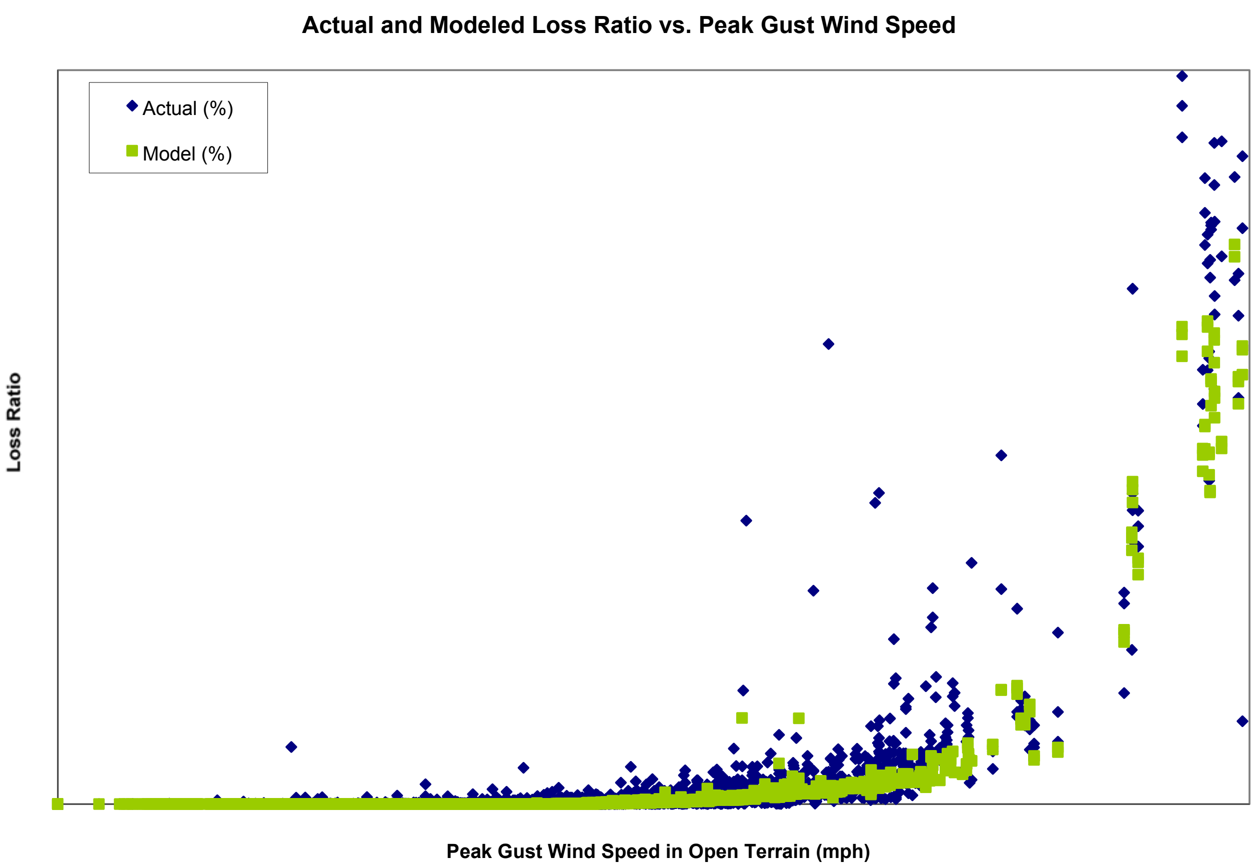


Figure B-20. Modeled and Observed Total; Loss ratio vs. Wind Speed

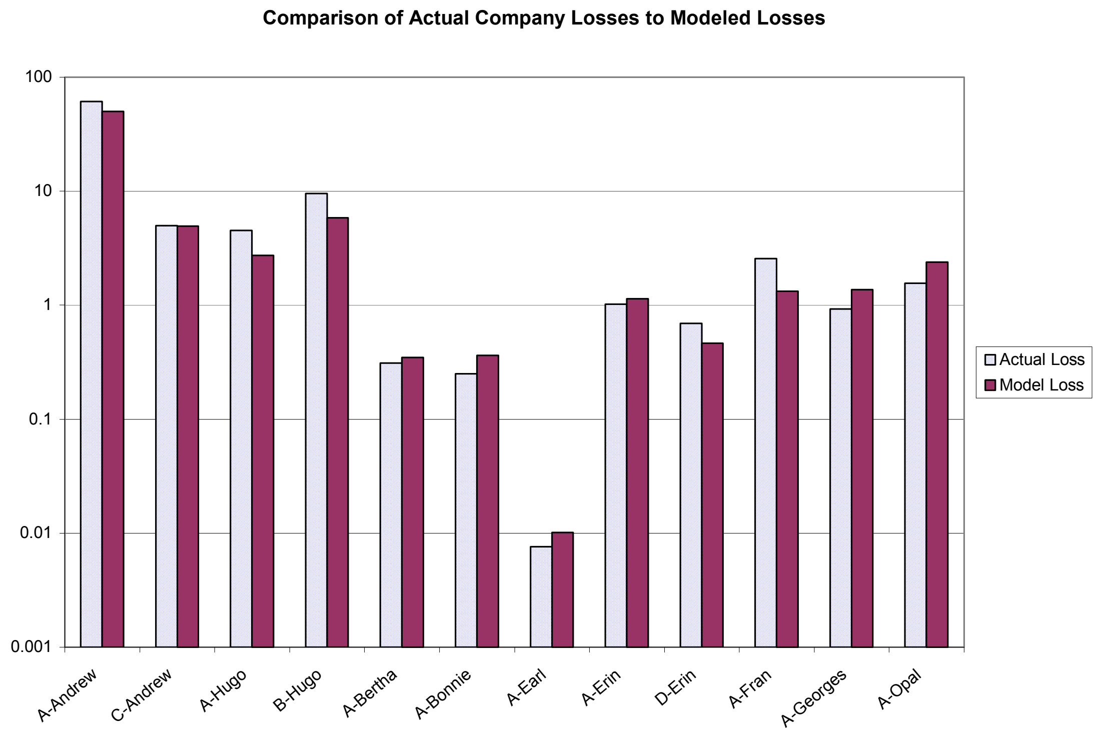


Figure B-21. Comparison of Modeled and Observed Total Losses (Homeowner Policies)

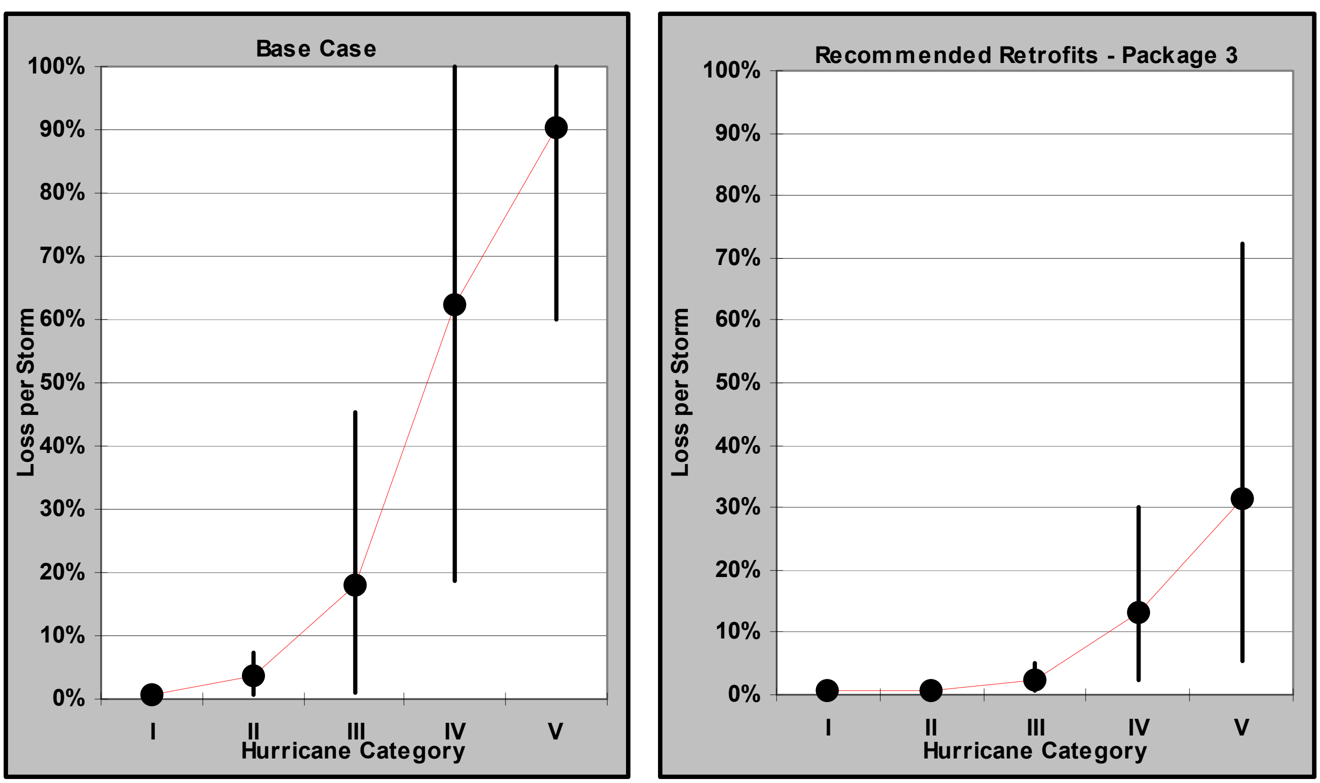


Figure B-22. Predicted Loss vs. Storm Category for an Existing Building and the Same Building With Several Mitigation Retrofits. Dots Represent the Mean Loss and Vertical Lines Represent the 10% to 90% Range of Loss.

APPENDIX C:

WIND RESISTIVE FEATURES AND LOSS ANALYSIS FOR EXISTING CONSTRUCTION

APPENDIX C: WIND RESISTIVE FEATURES AND LOSS ANALYSIS FOR EXISTING CONSTRUCTION

C.1 Introduction

This appendix includes three main sections. Section C.2 presents general definitions of the wind resistive features used in the development of the loss relativities for existing construction in Section 3. Section C.3 discusses some of the wind resistive features not considered as separate rating variables in this study. Section C.4 discusses how the computer runs were performed and the results integrated to produce the final relativity tables in Section 3.

C.2 Wind-Resistive Rating Variables for Existing Construction

This section generally defines the wind resistive features used in the modeled buildings. This information is intended to provide only general guidelines that can be used by insurers to develop more detailed definitions and procedures for their individual filings.

C.2.1 Roof Covering

The most common roof covering materials in Florida are composition shingles and tiles. Other roof covering materials used for residential construction in Florida include built-up, metal, slate, wood shakes, and single ply membranes. A key factor in roof covering performance is the method of attachment of the roof covering to the roof deck.

The Florida Building Code 2001 (Section 1504) has material requirements and attachment specifications that are superior to common roof covering building practices in the past. For composition shingles, these requirements include improved self-seal strips and compliance with ASTM D-3161 (Modified for 110 mph). This requirement is commonly referred to as the "110 mph" rated shingle.

The roof covering specifications of the 1994 SFBC also require improved attachment methods and testing to a similar protocol. Therefore, these roof coverings are considered to be sufficiently similar to FBC roof coverings to be classified in the "FBC Equivalent" category in Table 3-1.

The rating of roof covering for existing construction can be achieved by requiring the roofing contractor to certify that a prior installation met the 1994 SFBC or the FBC 2001 requirements. Otherwise, the current house roof covering should be rated as non-FBC equivalent. Insurers should remind owners of existing houses that when they recover their roofs they need to have the contractor certify that the installation meets the FBC 2001, Chapter 15 requirements in order to receive the new roof covering credit.

C.2.2 Secondary Water Resistance

Secondary water resistance (SWR) is a layer of protection that protects the building if the roof covering fails. SWR was included in the FWUA class plan because of its cost-effectiveness as a mitigation technique. This mitigation technique is aimed at keeping rain water out of the house once the roof covering fails. Generally, roof coverings begin to peel off in peak wind gusts ranging from about 70 to 100 mph. The underlayment (felt) also is easily torn and becomes separated from the roof deck, exposing the house interior to water damage. Water enters through the space between pieces of the roof deck. SWR covers these seams and provides for a redundant water proofing of the house.

The most economical way to achieve SWR is to apply Self-Adhering Modified Bitumen Tape to the plywood joints. This self-adhering tape is generically known as Ice & Water Shield or Peel N Seal and is a rubber-like product applied directly to a roof deck to prevent damage from ice dams in northern climates. Here, the product is applied to the outside of a clean plywood/OSB deck prior to application of regular underlayments and roof covering. The most economical use of this product is to use 6″ widths as shown in Fig. C-1. This is done when a new roof covering is being put on the house.

Another way to achieve SWR is a foamed polyurethane structural adhesive applied from inside the attic to cover the joints between all plywood sheets. Figure C-2 shows this product installed in an attic. Note that this product is also used to reinforce the connection between trusses and roof sheathing, qualifying for improved roof deck attachment. Structural adhesives that meet AFG-01 should not be confused with foamed insulating products.

The verification of SWR must be done at the time of application since once covered, it is difficult to verify. The foamed structural adhesive applied from inside the attic, however, is readily verified with an attic inspection. Roofing contractors should complete a form to provide certification for the owner in order to receive this credit. Education of contractors is needed since the sealing of the plywood joints is a relatively new concept. If not carefully communicated, roofing contractors may incorrectly assume that the underlayment or hot-mopped felts are SWR. These standard roofing applications do not qualify for SWR because they may be blown off the roof deck at high wind speeds. In contrast, off-the-shelf self-adhering bitumen tape has been tested to negative pressures of over 150 psf without failure of the SWR strips.

C.2.3 Roof-to-Wall Connection

The roof-to-wall connection is another critical connection that keeps the roof on the building and acts to transfer the uplift loads into the vertical walls. This connection is key to the performance of the building due to the large negative pressures acting on the roof. Verification of the type of roof-to-wall connection requires access to the attic.

Figure C-1. Self-Adhering Modified Bitumen Strips Applied to Plywood Joints of Roof Deck

Figure C-2. Sprayed on Structural Adhesives to Seal Plywood Joints (SWR) and Strengthen Roof Deck Attachment

A common connection detail in non-hurricane prone areas is the toe-nail, where approximately 3 nails are driven at an oblique angle through the rafter and into the top plate. An example of a toe-nail connection is shown in Fig. C-3.

There are several manufacturers of metal connectors for hurricane uplift connectors and each company has a fairly wide line of products. For practical purposes, a classification is used herein to distinguish the uplift capacity of these connections based on connector type. The most important feature of any of these connectors, other than toe nails, is that the fasteners used to transfer the loads from rafter/truss to strap to top plate or side wall are always loaded in shear (perpendicular to the nail direction), or the strap is embedded into the bond beam of the masonry wall. Proper installation is critical to connector performance.

Some of the older straps in Florida are simply strips of galvanized metal that were pounded into shape on site to perform the same functions as the straps shown here. These galvanized straps were often 1″ by 1/8″ thick pieces of galvanized steel. If these straps are installed correctly and are not compromised by corrosion, they will perform adequately.

Our analysis for loss relativities has evaluated how four levels of roof-to-wall connections affect loss costs. These are summarized in Table C-1. The uplift resistance capacities are mean ultimate values based on tests results. By providing the ultimate capacities used in this study, we are indicating what actual values were used in the loss relativity calculations. The ultimate values are distinctly different from the design value of the connection. For example, a 386 lb rated clip has an ultimate capacity of about 866 lbs.

We offer the following general descriptions of these connections (see Fig. C-4):

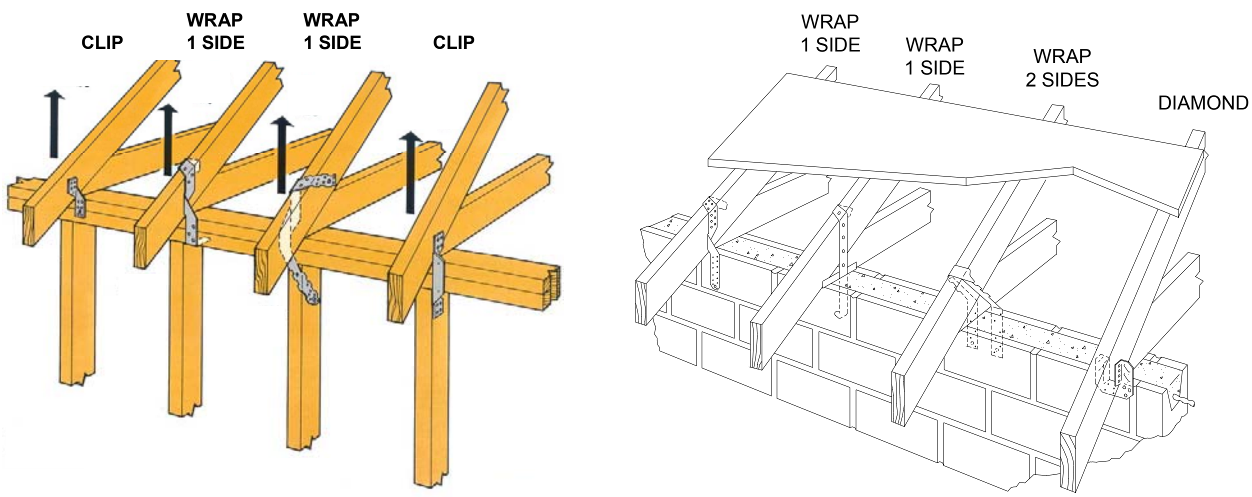
- **Clips and Diamond Connectors:** Clips are defined as pieces of metal that are nailed into the side of the rafter/truss and into the side of the top plate or wall stud. The metal does not wrap around the top of the rafter/truss, and the clip is only located on one side of the

Figure C-3. Example of a Toe-Nail Connection Used for Rafter-to-Top Plate Connection

Table C-1. Roof-to-Wall Connections Analyzed for Loss Relativities

Description	Typical Design Strength* (lbs)	Mean Ultimate Strength Used in Calculations (lbs)
Toe Nail (3-16d)	185	415
Clip	386	866
Wrap	535	1200
Double Wrap	891	2000

* Includes 60% increase for wind loading



(a) Wood Frame **(b) Masonry**

Figure C-4. Typical Hurricane Roof-to-Wall Metal Connector

connection. The approximate design capacity of this type of strap is in the order of 400-500 lbs uplift. The approximate design uplift capacity for two clips is 800 lbs. A diamond is a piece of metal that has a slot in the middle to accept the rafter, and nails to the outside edge of the top plate. It has a design uplift capacity of approximately 500 lbs.

- **Straps: Wrap 1 Side and Wrap 2 Side:** The wrap style straps are attached to the side and/or bottom of the top plate and are nailed to the rafter/truss. Straps that are wrapped on both sides have double the capacity of a single strap.

Verification of the type of roof-wall connector requires an inspection for accurate house ratings.

C.2.4 Roof Deck Material and Attachment

The performance of the roof deck is of critical importance in keeping hurricane losses to a minimum. It usually only takes the loss of a small portion of the roof deck before the losses for the building become substantial. Rain enters the building and produces water damage to the interior and contents.

C.2.4.1 Wood Decks. Roof decks for residential occupancies in single family buildings and buildings with 1-4 units are typically constructed with plywood, OSB, dimensional lumber, tongue and groove boards, or batten.

The most common roof deck types are plywood and Oriented Strand Board (OSB) decks. Prior to the availability of plywood, the most common roof decking material was dimensional lumber or tongue and groove (T&G) boards. Dimensional lumber or T&G are usually 4″ to 8″ wide boards that are nominally 1″ thick (¾″ actual thickness) and are laid in a fashion that is parallel to the ridge or diagonal to the ridge. These roof decks are fastened by at least two nails per truss/rafter connection. Because of the inherently large number of nails in dimensional lumber or T&G, the uplift capacity is generally far greater than typical plywood/OSB decks.

By far the most important feature of roof decks is the attachment to the framing, which is usually achieved by nail fasteners. Nail size, type, spacing, and penetration depth into the truss or rafters determines the uplift resistance of the deck. The difference in uplift capacity of 8d (2½″) nails at a typical nail spacing and 6d (2″) nails at the same spacing is a factor of about two times stronger, which makes a significant difference in deck performance in hurricanes.

The thickness of the deck material is important primarily in the determination of the penetration depth of the nail into the truss/rafter. Prescriptive building codes specify longer nails for thicker decks (see Table C-2). Thicker decks have an added advantage of adding additional weight to the roof which helps to resist whole roof failures. However, thicker decks by themselves do not make a notable difference for deck attachment failures as these are governed by local pressures. The effect of deck thickness is therefore relatively minor and has not been analyzed in this study.

For existing construction, the only practical way to determine deck type and fastener type and spacing is by a trained inspector going into the attic.

We have analyzed roof deck attachments for the following cases:

Level A. Plywood/OSB nailed with 6 penny common nails at 6″ spacing on the edge and 12″ in the field on 24″ truss spacing. This provides for a mean uplift resistance of 55 lbs per square foot.

Level B. Plywood/OSB nailed with 8 penny common nails at 6″ spacing on the edge and 12″ in the field on 24″ truss spacing. This provides for a mean uplift resistance of 103 lbs per square foot.

Level C. Plywood/OSB nailed with 8 penny common nails at 6″ spacing on the edge and 6″ in the field on 24″ truss spacing. Within 4′ of a gable end the nail spacing is 4″. This provides for a mean uplift resistance of 182 lbs

Table C-2. Nailing Patterns from Standard Building Code

Typical Roof Sheathing Nailing Pattern – Non-High Wind Zones (SBC 1997)			
Thickness of Sheathing	Attachment Size	Edge Spacing	Field Spacing
½″ or less	6d nails	6″	12″
19/32″ and up	8d nails	6″	12″
Typical Roof Sheathing Nailing Pattern – High Wind Zones (SSTD 10-93)			
Thickness of Sheathing	Attachment Size	Edge Spacing*	Field Spacing
15/32″ and up	8d common nails	6″	6″

* At gable ends, sheathing nails should be installed at 4″ oc.

per square foot for non gable end locations and 219 lbs per sq foot for gable end locations.

Level D. Dimensional Lumber and Tongue and Groove Decks. Over 90% of the RCMP inspected dimensional lumber decks have 8d or greater nails. We have analyzed the case of two 8d nails per board, producing a mean uplift resistance of 338 lbs per square foot.

The panel uplift resistances given above are based on a combination of experimental data obtained from individual nail withdrawal tests and laboratory uplift tests performed using full sizes (4′ by 8′) sheets of plywood and OSB. Note that the uplift resistance of a panel is dependent upon the species of wood of the underlying truss or rafters and the moisture content of the wood. Decks attached with screws and or adhesives should be rated according to the equivalent uplift resistance of these attachments using the categories above.

Based on the RCMP and FWUA inspections in Florida, more than about 60% of the existing roof deck/attachments will be superior to Level A (6d nails at 6/12 spacing).

There are many technical issues that affect the proper rating of the roof deck (see Fig. C-5), including a great variety of available nail sizes, nail penetration depths, the consideration of missed nails, etc. Proper inspection guidelines and training are essential to determining the deck attachment of existing residences. Without proper training/retraining, roof deck attachment ratings will likely have significant classification errors, possibly greater than 30%.

Batten deck is a system where boards are laid perpendicular to the rafters and spaced apart from each other. This deck forms the basis for which to install wood shakes or wood shingles. There is no continuous deck in this roofing system. Batten decks with wood shakes

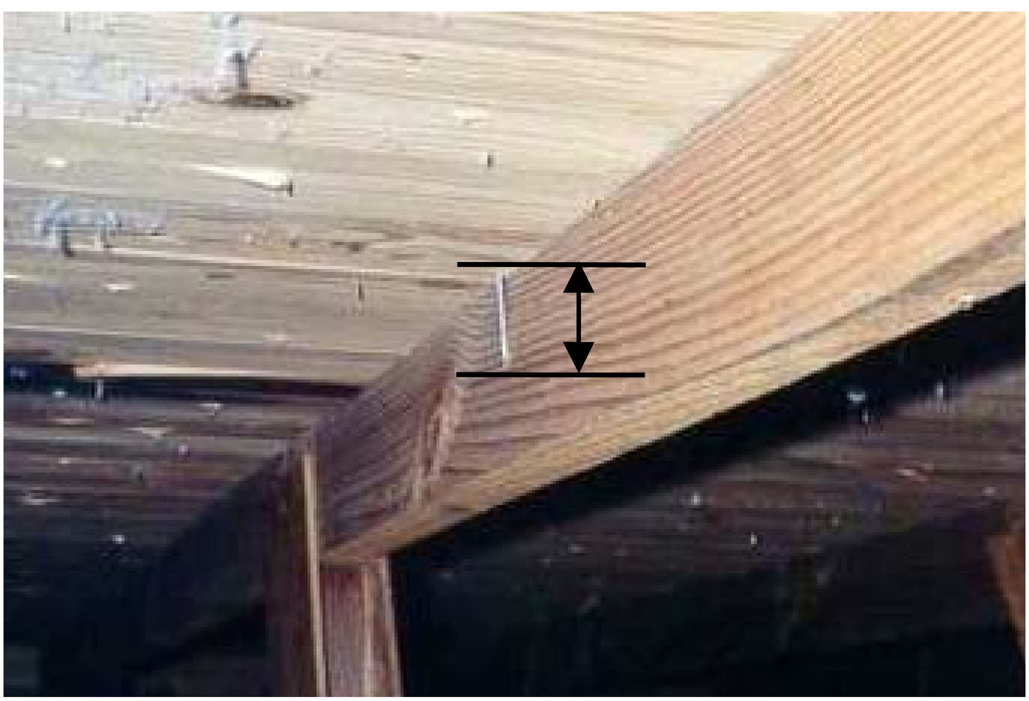


Figure C-5. Roof Deck Attachment Rating Requires an Attic Inspection.

have not been analyzed separately in this study. An interim recommendation is to use Roof Deck Attachment Level B.

C.2.4.2 Concrete Roof Deck. Although not very common in residential construction in Florida, there are homes constructed with concrete roof decks. When these building are equipped with wind-borne debris impact resistant opening protection, they are extremely resistant to building failures. Damage to the building will largely consist of damage to the wall finish and roof covering (if any). The hurricane loss costs are therefore reduced dramatically.

A reasonable requirement for this type of construction is that the roof deck be designed and constructed in accordance with the provisions of ACI (American Concrete Institute) 318, including integral construction with a masonry wall system.

C.2.5 Roof Shape

Roof shape refers to the geometry of the roof and not the type of roof covering. There are many common roof shapes in residential construction. Gable and hip are the most common, although flat, Dutch hip, gambrel, mono slope, and many shape combinations are possible. Figure C-6 illustrates some of these shapes. Gable roofs have vertical walls that extend all the way to the top of the inverted V, and are very common throughout Florida. A hip roof has sloping ends and sloping sides down to the roof eaves line. Predominant roof shapes vary by region within the state.

Roof shape determines the aerodynamic pressure loads experienced by the roof due to wind flow and wind direction. As an illustration of roof shape aerodynamics, Fig. C-7 shows wind tunnel measured pressures for hip and gable roof shapes. In this figure, the winds are quartering winds (angled at about 45° to the buildings), which typically produces the highest suctions on the roof for these shapes. For this wind direction, the maximum loads on ports of the gable roof are almost twice those of the hip for the critical locations with the highest negative pressures. The lightly shaded contours indicate higher negative pressures and the hot spot (for this wind direction) at the edge of the gable near the ridge line is clearly visible. Hence, with the same deck nailing pattern and or roof covering, the gable will experience more damage that the hip roof and that is why roof shape is an important rating variable.

While these basic roof shape aerodynamics have been fairly well known for a number of years, the national design standard has been slow to codify the differences. The ASCE 7-98 Standard (used by the FBC 2001) does not distinguish gable from hip (for the common roof slopes of 10-30°), defaulting to loads for a gable roof. However, the forthcoming ASCE 7-02 Standard will recognize the pressure coefficient differences between these two common shapes.

Gable and hip shapes and their combinations comprise more than 80% of the residential building stock. For practical reasons, we consider only two basic roof shapes in this study: hip and gable. For classification purposes, these classes can be thought of as "hip" and "other". That is, a roof is either a hip, per the definition of hip, or it is in the "other" category.

This study has not attempted to quantify the effects of complex roof shapes, including architectural gables, dormers, gable porches, hip roofs with small flat roof porches. A basic guideline is to classify the shape as hip if it is hip shape and has no gable end that exceeds 50% of a major wall length.

Insurance classification procedures for roof shapes are best developed with many example photos and supporting discussion/rules to ensure accurate ratings. Because the relative difference in hurricane losses for roof shape is significant, roof shape ratings should be done as accurately as possible.

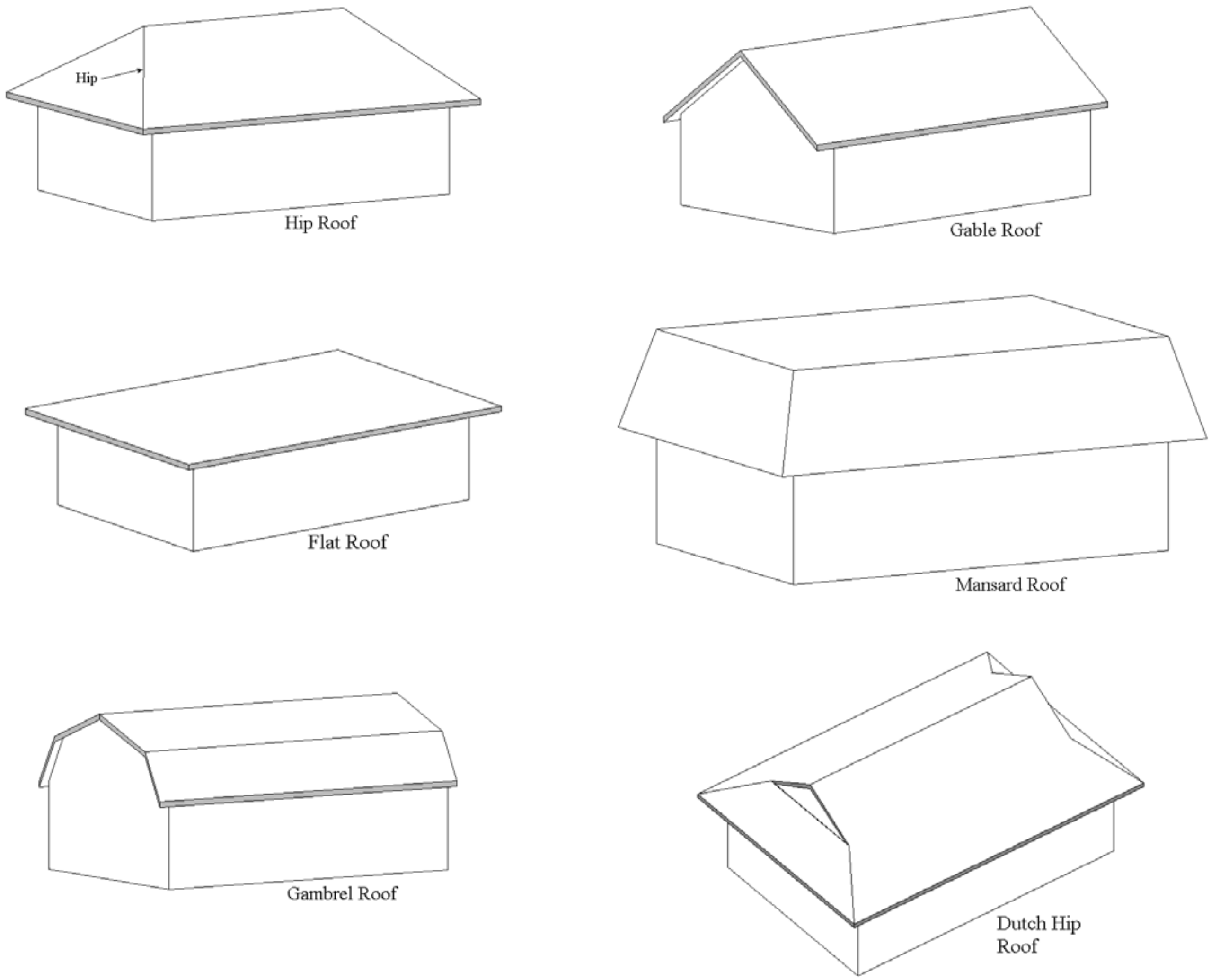


Figure C-6. Roof Geometry Shapes

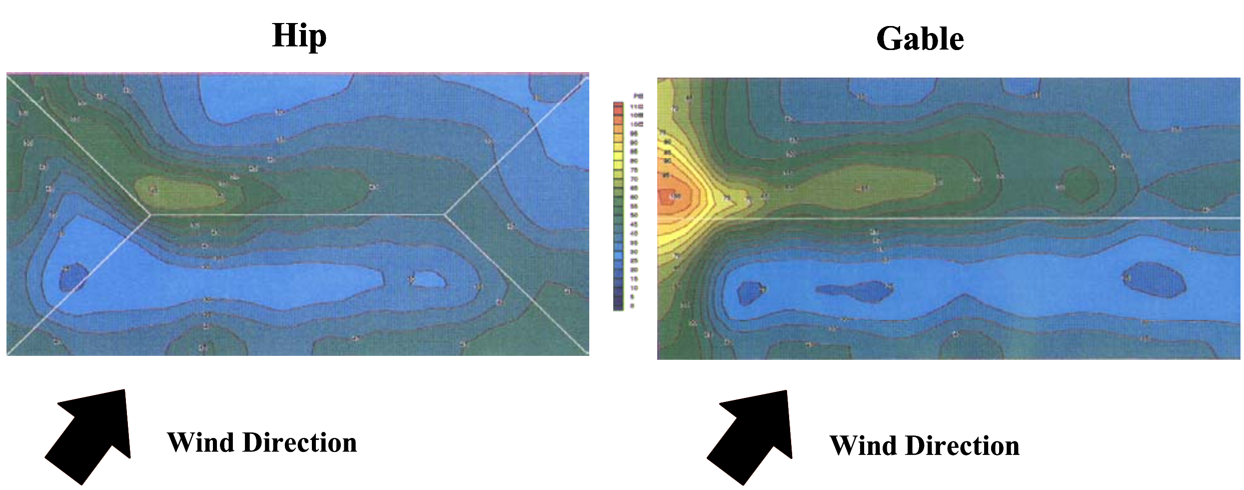


Figure C-7. Wind Pressures on Hip and Gable Roof Shapes for a Single Wind Direction

C.2.6 Gable End Bracing

The end walls of gable roofs extend vertically to the sloping roof line. These gable end walls, if not properly built, have been noted to fail outward due to the negative suctions on the wall.

There are two ways that gable end walls fail. The first mode of failure occurs when the roof deck fails on the gable end and the gable end truss becomes unstable due to lack lateral restraint at the top of the end truss or rafter. The gable end wall therefore will generally collapse. This failure mode can be prevented by properly securing the roof deck at the gable end with higher density nailing patterns. Once the roof deck is lost, the building experiences high losses because of the vast amounts of rain water that enter the structure. Hence, the gable end failure in this case is not the primary cause of the high loss, but a result of the failure of the roof deck. Improved roof deck nailing and/or bracing of the top chord of the gable end can prevent this type of failure. However, if the roof deck fails the building will still have high losses regardless of whether the gable end wall fails or not.

Another failure mode for gable end walls includes failure at the bottom chord of the truss. There are many ways to properly brace a gable end wall, and this is further complicated by the wide variety of custom engineered solutions available. There are four general types of gable end wall construction that are commonly seen in the field. These are masonry walls, balloon framed walls, truss walls, and platform or standard frame walls. For information on gable end bracing, refer to SSTD10, SBC-97, and the IBHS Guide, "Is Your Home Protected From Hurricane Disaster?".

Bracing of gable end walls is relatively easy provided there is attic access. Figure C-8 shows an example of cross bracing from the gable end to the second truss.

The HURLOSS analysis for gable end failures has focused on bottom chord failures for improperly braced gable ends. No analysis was performed for top chord failures, as experiments would be required to provide supporting data to model this failure mode properly.

C.2.7 Openings

Openings in the wall and roof include windows, doors, sliding glass doors, skylights, and garage doors. Gable end vents and other roof vents are not considered openings for purposes of this study. Openings are vulnerable to wind-borne debris impacts in hurricanes and other windstorms. Typical single and double strength glazing are easily broken by impact from light weight debris that is generated from roof covering failures during high winds. In addition, heavier debris, such as roof tiles, 2″ by 4″ wood members, and plywood will easily penetrate openings that are not protected by impact resistant products.

The protection of openings is perhaps the greatest single loss mitigation strategy for a building. The reason for this is that once a window or door fails, the pressure inside of the structure increases due to the breach in the building envelope. The positive pressure inside of the building produces an additive load on the building envelope. The increase in load can be up to twice the loads the building experiences without a breach of the envelope. This approximate doubling of the load can easily put the roof, other windows, doors, in a overload situation. The result is often additional failures that occur after the original opening fails. This type of failure sequence has become a well documented phenomena in the wind engineering literature since the 1970s. Unfortunately, the protection of openings for debris impact has only recently made it into certain design standards and building codes. Hence, many buildings remain vulnerable to debris impact failures of unprotected openings.

Figure C-8. Gable End Bracing Secured with Metal Connections

The first building code to adopt protection requirements in the United States was the South Florida Building Code in 1994. The testing protocol in this code requires the protection device to withstand impacts by 2 by 4 studs followed by pressure cycle loading. The Standard Building Code's SSTD-12 has similar requirements. In 1999, the ASTM also came out with a debris impact standard (E 1996) and test (E 1886). These standards include requirements for both wind pressure and debris impact. Opening protection products manufactured before 1994 would not have been tested to these standards. Figure C-9 shows an example of opening protection with the Miami-Dade County sticker showing product compliance with test standards.

There are many untested opening protection products that have been installed in Florida both prior to and after the development of the impact/pressure cycling standards. In general, these products provide some protection for pressure and missile impact, but there is no practical way to quantify all the possible variations in debris impact and pressure cycling resistance. The FWUA class plan has an "Ordinary" protection level based on ASCE 7-88 wind pressure design that provides an intermediate level of protection between the Miami-Dade standard and no opening protection.

For purposes of estimating the loss relativities for an intermediate level of protection, we have analyzed an intermediate level of opening protection that corresponds to one half of the impact resistance (175 ft lb of energy) of the Miami-Dade standards. This level is referred to as "Basic" and covers the small (4.5lb 2″x4″) missile in ASTM E 1996. This level is included in the loss relativity analysis as an intermediate class of protection. If an insurer has an existing protection credit that gives credits for protection levels less than Miami-Dade, then it could use the "Basic" level of relativities herein as a guideline for how those credits would fit into the main loss relativity tables. Note that no analysis has been done for plywood shutters and that the "Basic" category may over state the loss reduction of plywood shutters.

The analyses performed herein for opening protection are for two cases:

1. Only glazed openings protected.
2. All openings protected, including windows, doors, skylights, garage doors.

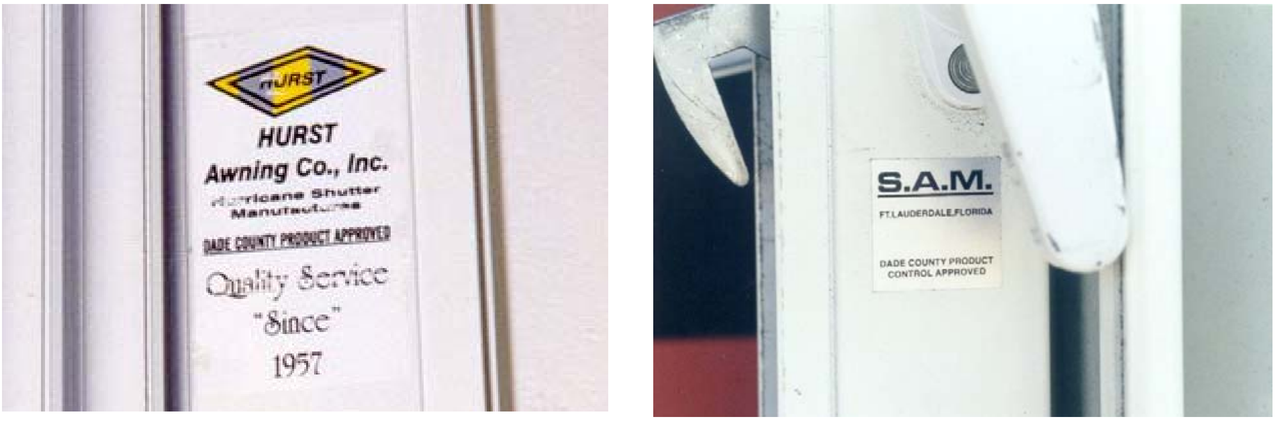


Figure C-9. Two product approval sticker on accordion shutters indicating that they meet Miami-Dade County impact resistance and wind pressure load standards. These labels contain the words "Dade County Product Approved" or equivalent.

A glazed opening refers to glass or a transparent or translucent plastic sheet used in windows, doors, or skylights (ASCE 7-98). For the first case, entry doors and garage doors (which do not contain glazing) are not protected. This case was analyzed because there are quite a few homes with protection over windows and other glazed openings but no additional protection over solid (non-glazed) entry doors or garage doors. In addition, this case also corresponds to the FBC that only requires opening protection over glazed openings (except in Miami-Dade and Broward Counties). We did not analyze the case when some of the windows and doors are protected and other windows and doors are not protected. For the second case, all openings are protected, including all non-glazed doors.

C.2.8 Wall Construction

The most common two types of wall construction used for single-family residential construction are wood frame, masonry, and combinations of the two. The different construction materials are important for fire resistance considerations, but are less important for wind resistance. Masonry walls are further distinguished by whether or not there is steel reinforcing to carry vertical and horizontal loads.

Insurance companies have generally rated buildings by wall construction material. However, it is likely that there are many rating errors since wood frame buildings with brick veneer may have been incorrectly rated as masonry walls. Also, many homes in Florida have an exterior stucco finish, which can be applied over a number of wall construction materials, including masonry, wood frame, insulated concrete forms, etc. Therefore an important consideration for insurers is whether or not to accept the wall construction information they may have in their database or obtain an updated wall construction certification as part of the overall procedure to determine the proper building class based on all the important wind-resistive rating features.

Frame construction is composed of a stick frame made from wood or metal studs and is often sheathed with plywood or Oriented Strand Board (OSB) upon which an exterior finish is installed.

M*asonry* construction is built from Poured Concrete, Insulated Concrete Forms (ICF) or Concrete Block Masonry Units (CMU´s) which may be left unfinished, stuccoed, or have a veneer system hung from the masonry units.

Reinforced Masonry construction has exterior walls constructed of masonry materials that are reinforced with both vertical and horizontal steel reinforcement and are relied upon for structural stability. It is important that the vertical reinforcement is fully grouted in the hollow cells of CMU, and that horizontal reinforcement be fully grouted in specially formed units. Tilt-up or poured concrete wall units will be reinforced with reinforcing steel both vertically and horizontally.

There are inspection techniques that can distinguish frame, masonry, and reinforced masonry wall construction. With appropriate training, an inspection of an existing building can accurately determine the proper classification of reinforced masonry versus masonry.

The model houses analyzed in this study were either all masonry, all wood frame, or all reinforced masonry. We did not analyze mixed masonry-wood construction. In general mixed construction consists of masonry first floors and wood frame second floors. A conservative rule is to classify the building as wood frame if wood construction is more than about a third of the exterior wall construction of the building.

C.2.9 Wall-to-Foundation

Foundation failures from wind forces alone are very rare. Typically, foundation failures associated with hurricanes occur when the surge from the water damages the foundation and structure.

Typical foundations include the following, as shown in Fig. C-10:

- Crawl space (Stem Wall)
- Basement
- Slab on Grade with Stem Wall
- Monolithic slab
- Piles
- Piers/Posts

A crawl space is a perimeter foundation that creates an enclosed under-floor space that is not habitable. The perimeter foundation is typically a continuous footing with a stem wall that is attached to the wall/flooring structure of the building. The interior area in a crawl space may or may not extend below grade. Alternatively, a basement foundation is a wall foundation that extends below grade and encloses an area that may be used for living space or storage.

A slab on grade foundation with a stem wall is a concrete floor that is supported directly by the soil, and an independent stem wall that supports the weight of the building. A monolithic slab is a concrete floor that has an integrated footing that supports the weight of the building.

Pile foundations are necessary when the weight of the building must be transmitted to a deeper soil layer that is more stable, or when the structure must be elevated above required flood elevations. Pier or Post foundations are sometimes an economical alternative to stem wall perimeter foundations. These foundations may or may not have bracing between posts/piers depending on the height of the post/pier compared to its width. There may also be bracing or in-filled masonry walls between the posts and piers to resist lateral loads. Note that pile foundations are typically much deeper than post/pier foundations.

Inspections of foundation attachments are not practical for common slab-on-grade construction. Inspections of stem wall foundations require access through a crawl space. Because of these issues and the fact that foundation failures are very rare for hurricane winds (and, if they do occur, the house is usually significantly damaged from other failures), we have classified foundations into:

1. Restrained: Foundations are assumed to have sufficient horizontal and vertical restraining forces unless classified as unrestrained.

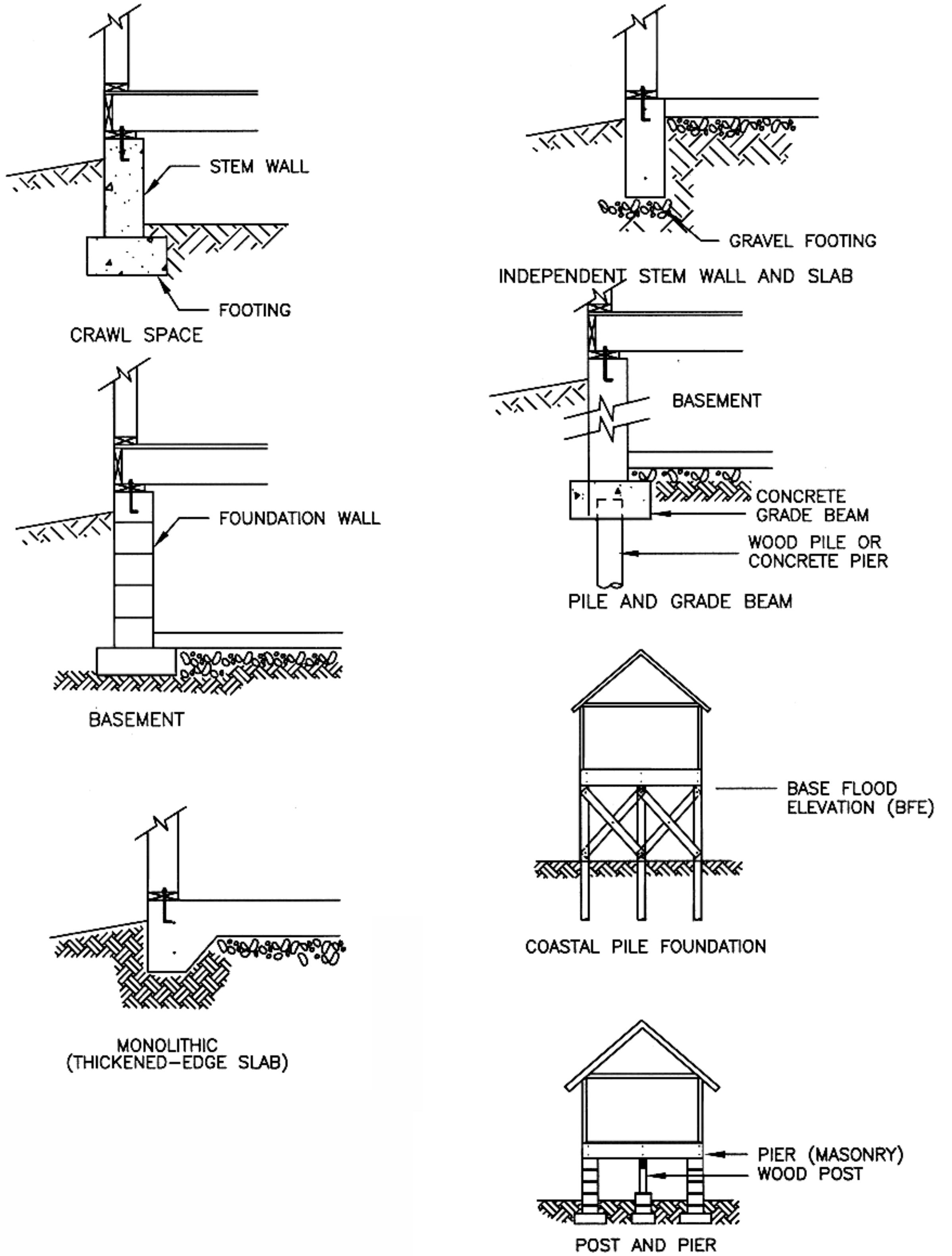


Figure C-10. Typical Foundation Types in Residential Construction (adapted from Residential Structural Design Guide, 2000 Edition, US. Dept of Housing and Urban Development, March 2000)

2. Unrestrained: Houses on posts, piles, or concrete blocks that rely solely on gravity and friction forces for resistance to uplift and lateral loads.

Almost all site-built houses will qualify as restrained. Building codes and inspections of houses confirm that there is almost always an attachment mechanism that provides suitable uplift and lateral resistance, especially when the building weight is also considered.

We have evaluated these two general classes of foundations for two failure modes – sliding of the building off the foundation and overturning of the entire building (i.e., the wind lifts the building up off the foundation). This analysis was performed as a separate sensitivity study.

C.2.10 Terrain

Terrain and the built environment significantly influences the pressure loads and debris impact loads on a building. The correct modeling of terrain (as defined by the aerodynamic roughness length, z_o) is one of critical importance in the prediction of wind loads, wind damage and, hence, wind loss. The surface roughness length, z_o, is a function of the density and height of the objects on the ground, including the buildings themselves and vegetation (i.e., trees). In areas of moderate to heavy tree density, the effect of the trees on the wind speeds near the ground can be as important as the surrounding building characteristics. An awareness of the importance of trees in the estimation of the surface roughness has prompted a change in the new wind loading provisions in the United States (ASCE 7-98), which now provides a methodology for the building designer to estimate the surface roughness taking into account the effect of trees.

The wind-borne debris environment depends on the location and type of adjacent buildings. Most residences are in suburban terrain with other low-rise structures. Buildings facing open fields and water are exposed to higher wind speeds and have higher pressures. In South Florida, the trees are shorter than those in North Florida and the surface roughness is correspondingly different.

Terrain is treated as a rating variable in this study for existing construction in the following manner:

1. Terrain Category B (Inland): All existing houses not on a barrier island nor within 1500 feet of the mean coastal high water line.
2. Terrain Category C (Coastal): All existing houses on a barrier island or within 1500 feet of the mean coastal high water line.

This classification basically follows the terrain exposure categories specified in the Florida Building Code (Section 1606.1.8) for new construction. While this is a simplified representation, it serves to capture the significant difference in loss costs and loss costs' relativities for buildings situated in highly vulnerable coastal locations.

C.3 Wind-Resistive Features Not Considered

Several features that can influence damage and loss in a hurricane were not considered in this study. These include building height, porches, carports, and skylights. Other features were considered in the modeled houses, but were not treated for classification or rating purposes. The following paragraphs discuss the rationale for omitting these variables and/or not treating them as separate rating variables.

Building Height – Although the height of the building is an important variable for single family residential buildings, all the modeled houses used in this study are one story buildings. One and two story residences generally fall into building heights less than 30 feet and the loads on the buildings are very sensitive to the building height. Significant differences in loads can result between buildings 15 feet tall and 25 feet tall because of the exponential nature of the vertical wind profile. Additional research is suggested to produce a public domain document on the difference in one and two stories and, at the same time, address building code issues that could improve the design requirements for two- and three-story residences.

The base case loss costs computed by insurers can be based on the appropriate mix of the number of stories in their portfolios (if they have this information) and the relativities herein can then be applied without building height (number of stories) treated as a separate rating variable.

Tile Roof Coverings - Tile roofs were not analyzed in this study. Tile roofs are different from shingle roofs in several important respects. First, they provide added mass to the roof, reducing the effect of the uplift forces. This added self weight (8-10 psf) can significantly reduce the wind induced uplift loads acting at the truss-wall connection, reducing the likelihood of whole roof failures. Thus, the loss relativity value for stronger roof wall connections for tiled roofs is less than that for shingle roofs. Second, however, these roof covers are much more vulnerable to debris impact damage and are also more expensive to replace. These factors make tile and other heavy roof covers a distinct class that insurers may want to consider separately. The method of attachment of tile roof covers is also a key consideration if an insurer chooses to rate tile roofs distinctly.

Percent Glazed Openings – The modeled houses have about 14% glazed openings as a percentage of wall area. The more openings in a building, the more vulnerable it is to damage, particularly for the case of no opening protection. When the openings are protected, there is much less sensitivity to the percentage. For simplicity, this variable was not treated as a separate rating variable.

Skylights – Skylights are vulnerable to debris impact failures, just as any other opening. Since we are not treating percent openings as a separate rating variable, skylights are also not considered as a separate rating variable. Skylights are treated like any other opening in terms of protection level.

Garage – Two of the model houses have two car garages and one does not have a garage. Hence, the effect of garages is included in the results (which average the loss costs for the three houses) but garage is not treated as a separate rating variable. The rational for omitting the presence of garages and garage door size as a separate rating variable is that the garage door is treated as an opening, with its level of protection treated under opening protection. That is, the opening protection level (none, basic, hurricane) applies to all openings, including garage doors. This approach simplifies the application of the relativities and the numbers of combinations required to be considered.

Porches and Carports – Porches and attached carports are vulnerable to failure in hurricanes. They generally are not a primary contributor to loss costs unless their failure opens up the main building envelope. Porch connections are difficult, if not impossible, to inspect since they are generally hidden and not accessible. Therefore, for practical reasons and the expected minor contribution, on average, these features were not considered.

C.4 Analysis of Loss Costs Relativities

The HURLOSS model was run in its individual risk analysis mode to produce loss costs for each modeled house. The houses were modeled with the wind-resistive features summarized in Table 3-1 and described previously. Two sets of runs were made for the two different terrain categories.

In order to keep the computational time reasonable, we separated the variables into two groups. The first group included the variables judged to have the greatest influence on loss costs. This includes roof covering, secondary water resistance, roof-to-wall connection, roof deck attachment, opening protection level, and roof shape. For roof deck attachment we considered the three nailing patterns for plywood deck and decided to analyze the dimensional lumber and reinforced concrete roof decks separately in separate sensitivity studies. A full combinatorial analysis for each Terrain category of these variables for the levels in Table 3-1, less two levels for roof deck, produces 288 combinations ($1 \times 2 \times 2 \times 2 \times 4 \times (5\text{-}2) \times 3$). Three houses were modeled for each such combination (using the geometries, sizes, and values in Section 2), making a total of 864 HURLOSS runs for each location.

The remaining variables in Table 3-1 were run in separate studies in which we analyzed a subset of the main combinations. Based on previous studies, these variables were expected to have less influence on loss costs. Hence if the effect is a few percent or less, then these factors can be introduced into the loss relativity through a simple adjustment, or, alternately ignored.

As described in Section 2, 300,000 years of hurricanes were simulated in HURLOSS. For each storm that produced winds greater than 50 mph peak gust winds at the house location, the loads on the building were computed and the response of the house modeled as the storm was stepped along it is simulated track. Damage and loss were computed and this process repeated for all storms. Loss costs were then computed for each combination of coverage and deductible. Three deductibles were analyzed (0, 2, and 5%) for each house and location.

The relativities are produced by the dividing the loss costs for each modeled house by loss costs of a "central" house, which is one that is close to the mode or most likely house. The "central" house is not necessarily the most likely for each region and area, but is near the central part of the frequency distribution, presented in Section 5.

As indicated in Section C.3, tiles are not treated as a separate class in this project. However, a separate HURLOSS sensitivity study indicates a complicated interaction with other rating factors that depend on the tile attachment mechanism. Well attached tiles can be beneficial on weak houses, but penalize well built houses because the roof covering costs tend to dominate the losses for houses with strong enveloped. Careful consideration of these effects is needed to fully understand the impact of tile roof coverings on loss costs.

C.4.1 Use of Engineering Judgement Factor

The relativities produced by this process directly reflect the differences in loss costs for different construction features on a set of modeled houses. Since the loss costs at each location are normalized by the loss costs of a "central" house at that same location, the relativities become multipliers to the insurer's estimated base loss costs for each territory. This normalization on a location-by-location basis clearly eliminates some of the modeling differences that depend on the specific approach. However, since the modeling process is not perfect and not all variables have been considered,[1] it seems prudent to apply a logical judgment factor that tends to compress the relativity range produced from these basic calculations.

[1] Recall that the full factorial combinatorial analysis has been limited to 7 rating factors (288 combinations × 3 houses for each of 31 locations).

The range in relativities from a weak to a strong house is one of the key output parameters that can be used to judge the reasonableness of the results. Toward this purpose, the following equation has been used

$$R = R^o + \left(R^o_{\max} - R^o\right)K \qquad \text{(C.1)}$$

to adjust the computed relativities. In Eqn C.1, R^o is the model computed relativity, $R^o_{\max}$ is the computed relativity for the weakest house, and K is the adjustment factor. If K is set equal to 1, then $R = R^o_{\max}$ for all the relativities and, hence, the value of $K = 1$ eliminates all the differences in the loss costs relativities. On the other extreme, K=0 is the equivalent of no adjustment to the calculated relativities. We choose to use a value of $K = 0.05$ in consideration of modeling limitations. This value provides a reasonable range of relativity from the weakest to the strongest house considering the averaging process used.

C.4.2 Variation of Relativity for Terrain B Locations

The variation of relativities by location was examined by plotting relativity R versus location for six cases. The six cases are shown in Table C-3. House 1 is a weak house and had the highest loss costs at each location. House 2 has a more common roof deck attachment and slightly improved roof-to-wall connection. House 3 is a strong house with an existing non-FBC roof covering. Houses 4, 5, and 6 are the same as 1, 2, and 3, respectively, but have improved roof coverings. Figure C-11 shows how the relativities vary for these houses across all seventeen inland locations for the case of 2% deductible and 50% contents. A similar plot for 2% deductible and 70% contents in Fig. C-12 shows the same trends. These variations were judged to be modest enough so that a single table of relativities would suffice for inland locations for existing construction for a particular deductible level. Therefore, the state-wide Terrain B relativities were computed by averaging across all 17 Terrain B locations for each house.

C.4.3 Variation of Relativity for Terrain C Locations

Plots of relativity variation by Terrain C location are given in Figs. C-13 and C-14 for 2% deductible. Because the variation from point to point is not excessive, a single set of relativities is also used for Terrain C. Similar to the Terrain B results, there is no significant difference in relativity for 50% and 70% contents ratios.

Table C-3. Houses Used to Plot Loss Costs Relativity versus Location

Houses for Relativity Plots				Roof Shape			
				Other		Hip	
Roof Covering	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	House 1			
			Ordinary				
			Hurricane				
		Clips	None				
			Ordinary				
			Hurricane				
		Single Wraps	None				
			Ordinary				
			Hurricane				
		Double Wraps	None				
			Ordinary				
			Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None				
			Ordinary				
			Hurricane				
		Clips	None	House 2			
			Ordinary				
			Hurricane				
		Single Wraps	None				
			Ordinary				
			Hurricane				
		Double Wraps	None				
			Ordinary				
			Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None				
			Ordinary				
			Hurricane				
		Clips	None				
			Ordinary				
			Hurricane				
		Single Wraps	None				
			Ordinary				
			Hurricane				
		Double Wraps	None				
			Ordinary				
			Hurricane				House 3
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	House 4			
			Ordinary				
			Hurricane				
		Clips	None				
			Ordinary				
			Hurricane				
		Single Wraps	None				
			Ordinary				
			Hurricane				
		Double Wraps	None				
			Ordinary				
			Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None				
			Ordinary				
			Hurricane				
		Clips	None	House 5			
			Ordinary				
			Hurricane				
		Single Wraps	None				
			Ordinary				
			Hurricane				
		Double Wraps	None				
			Ordinary				
			Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None				
			Ordinary				
			Hurricane				
		Clips	None				
			Ordinary				
			Hurricane				
		Single Wraps	None				
			Ordinary				
			Hurricane				
		Double Wraps	None				
			Ordinary				
			Hurricane				House 6

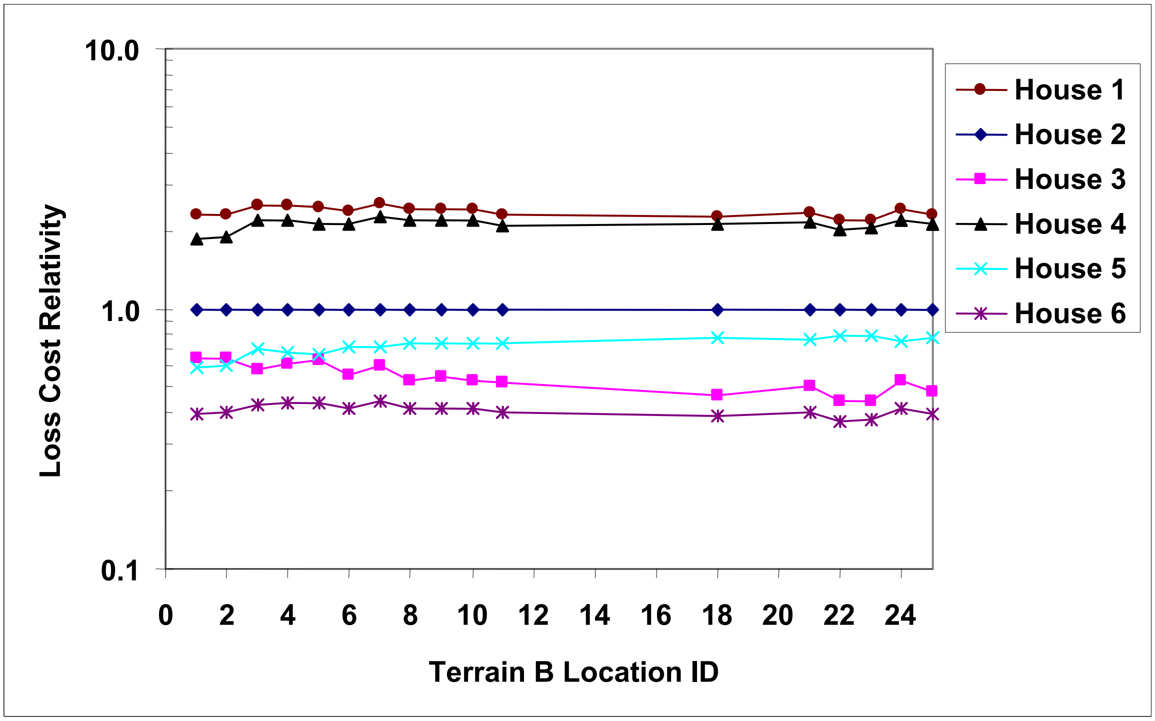


Figure C-11. Relativity Variation for Terrain B Locations for 2% Deductible and 50% Contents

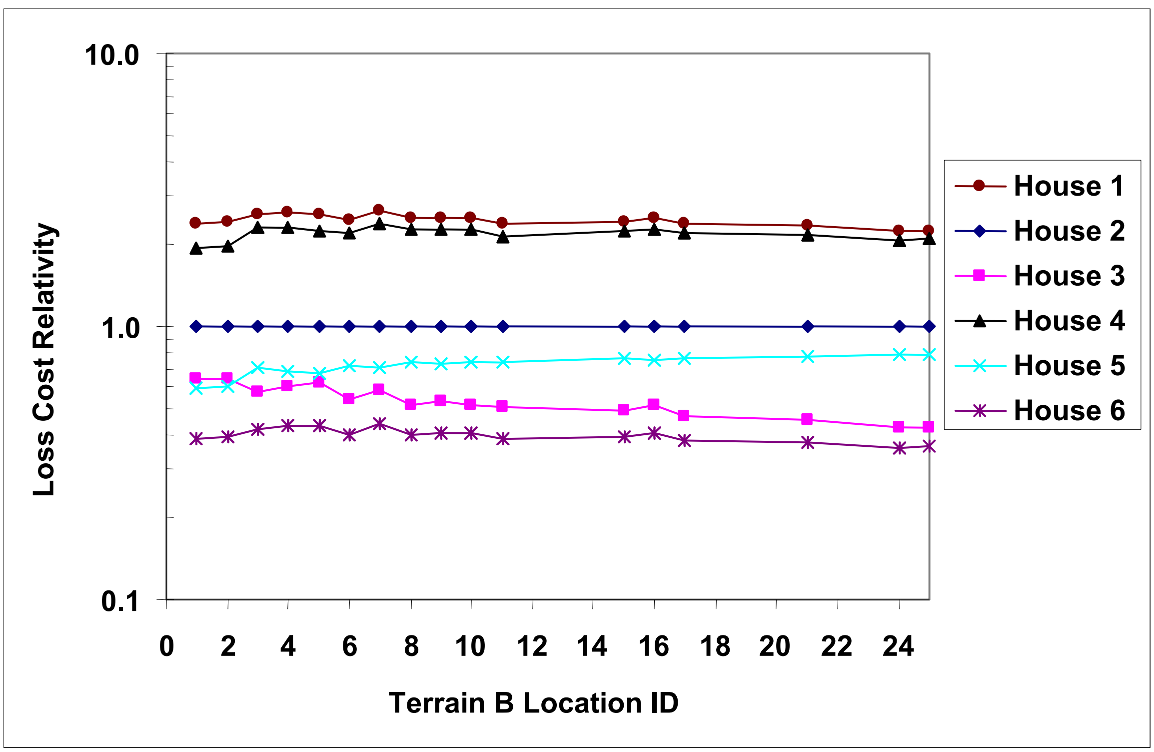


Figure C-12. Relativity Variation for Terrain B Locations for 2% Deductible and 70% Contents

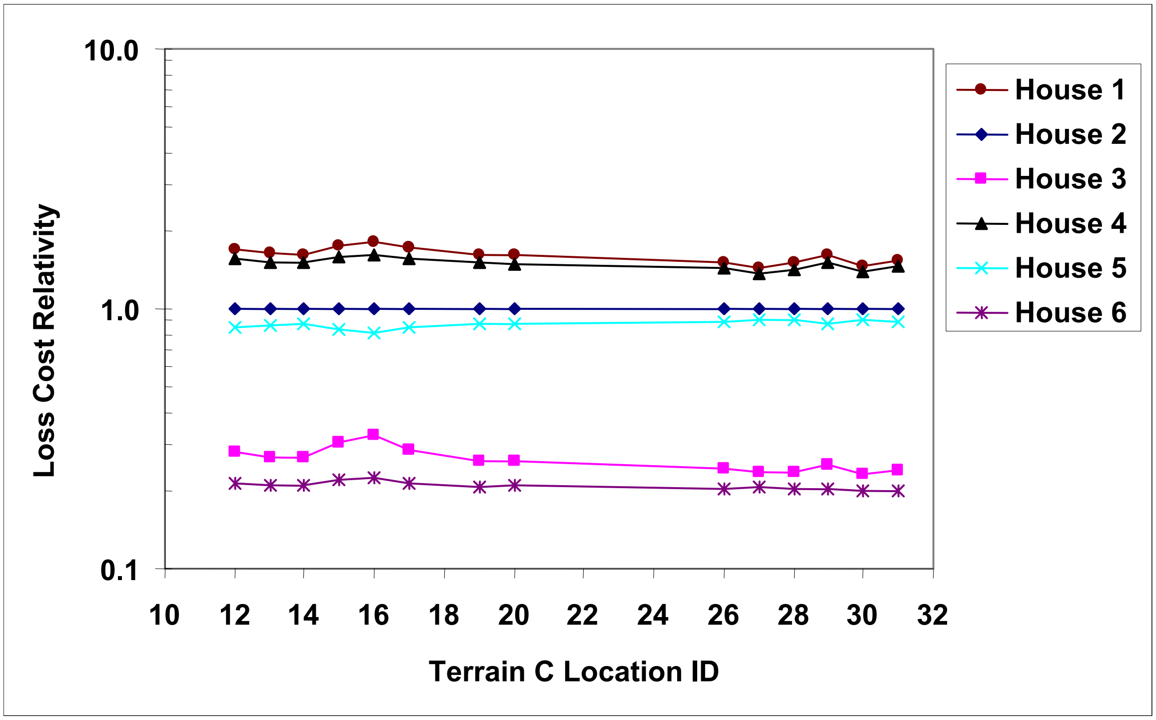


Figure C-13. Relativity Variation for Terrain C Locations for 2% Deductible and 50% Contents

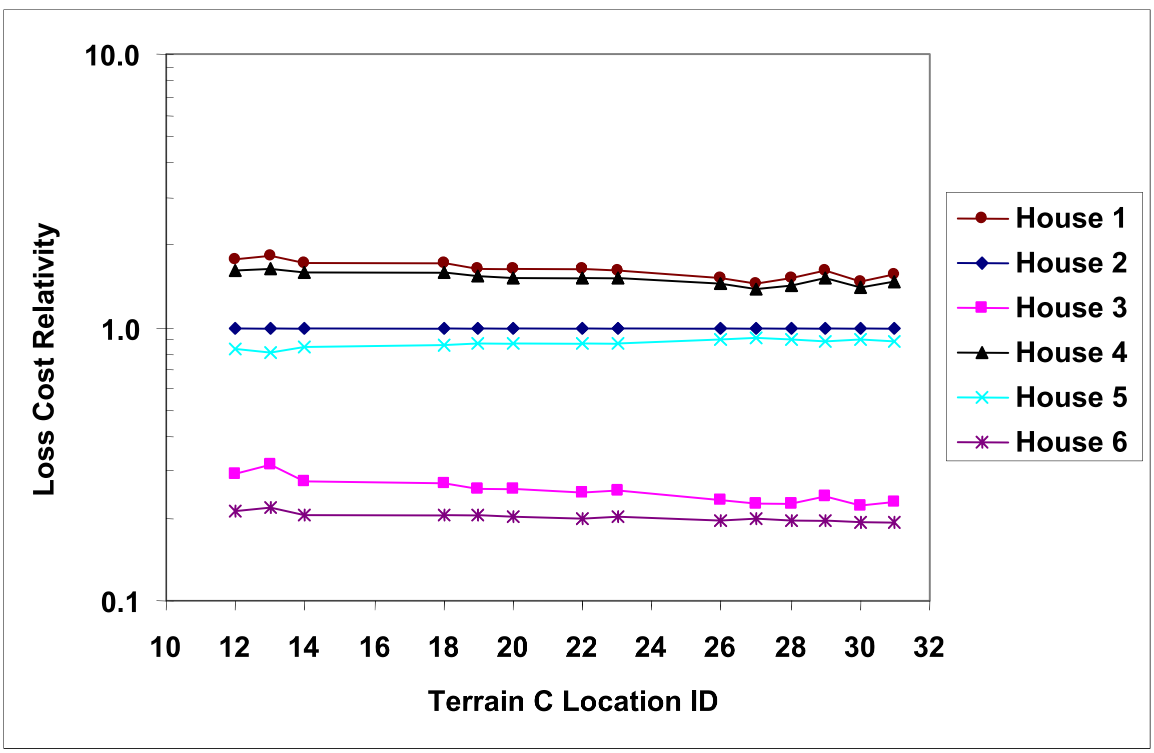


Figure C-14. Relativity Variation for Terrain C Locations for 2% Deductible and 70% Contents

APPENDIX D:

INDIVIDUAL BUILDING DAMAGE REPORTS

APPENDIX D: INDIVIDUAL BUILDING DAMAGE AND LOSS REPORTS

This appendix contains example reports produced from the HURLOSS analysis of individual buildings. The buildings correspond to a weak, moderate, and strong house. Each report consists of 5 pages and contains the basic information on the building, model number, location, and simulated wind climate. The damage plots show key information on building component performance. The reports are given for the three houses for two locations: Lighthouse Point and Miami. All reports are for Terrain C.

Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW1DK1PR100006C

HurReport - Single Family Residential

Building Description

Stories:	1
Primary Roof Shape:	Gable
Roof Cover:	Asphalt/Fiberglass Shingles
SWR:	No
Roof/Wall Connection:	Toe Nail
Roof Deck:	Plywood
Roof Deck Attachment:	6d/06/12/06
Wall Construction:	Stick Frame

Wind Climate

Num of Year Sim: 300,000
Sim File: \DCADOI\HurLossArchive\WindClimateData\SIMW00006.dat

Num Sim Per Storm:	30
100 Yr Wind Speed:	112 mph
250 Yr Wind Speed:	126 mph
1000 Yr Wind Speed:	145 mph
Annual Occ. Rate:	0.54633
Latitude (deg):	29.9371
Longitude (deg):	84.3393
Orientation:	Random
Inland Distance(km):	0.2
Terrain(m):	0.03
Location:	Lighthouse Point

Type	*Plan*	*Roof*	*Wall*	*Fen*	*Glazing*
Area (sf)	1800	1950	1808	421	241
Percent	NA	NA	NA	23%	13%

Protection Level	***Area (sf)***	***Percent ****
Annealed Glass	194	11%
Tempered Glass	47	3%

* percent of wall area for fens and percent of roof area for skylights.

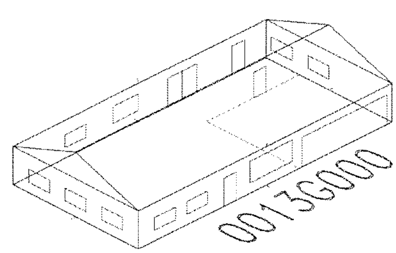
Fen:	*Windows*	*Doors*	*Sliders*	*Garage*	*Skylights*
Cnt:	10	1	2	1	0

Cat.	Number of Storms
0	148,366
I	11,807
II	2,839
III	761
IV	119
V	6
Total	163,898

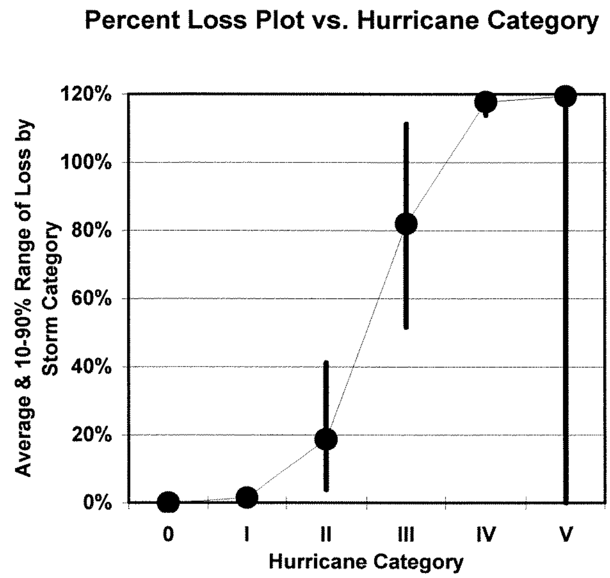
Economic Description

	Value	*Cap*
Building:	$100,000.00	1.25
Contents:	$70,000.00	1.00
ALE:	$20,000.00	1.00
Deductible	0/2000/5000	

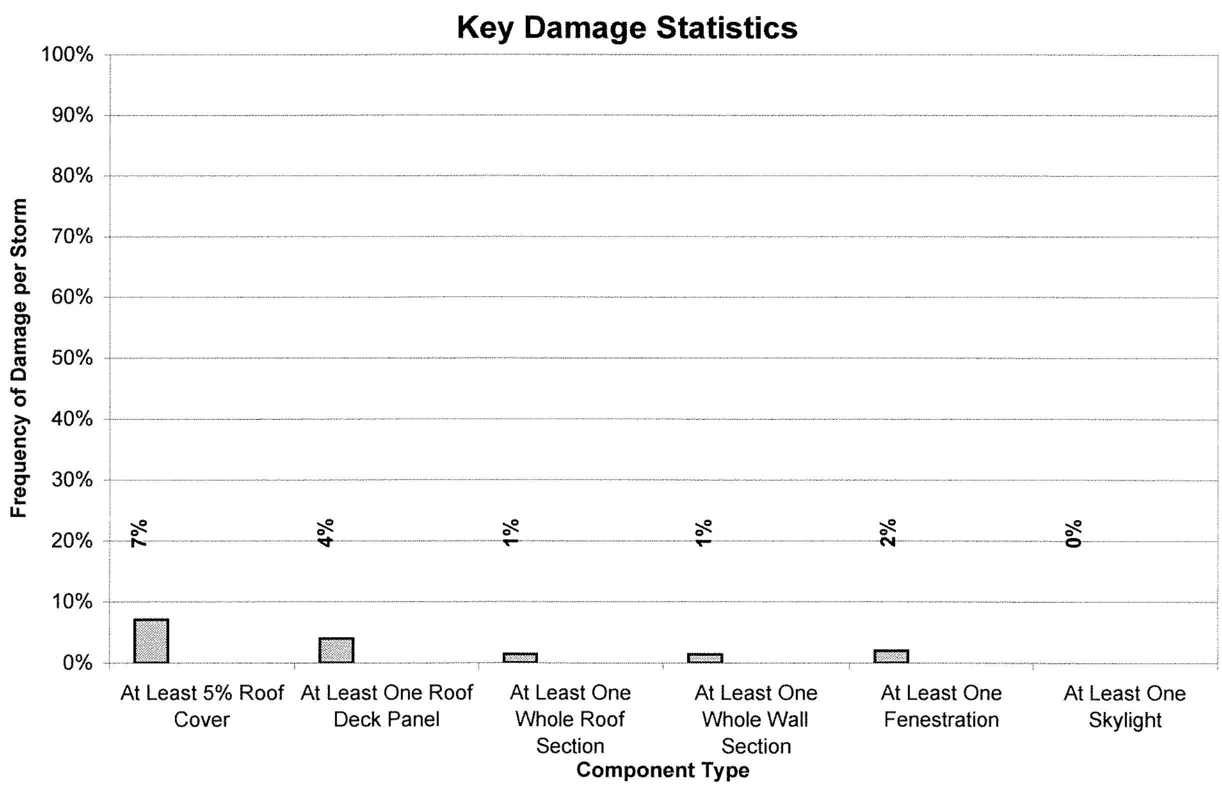
Cap Cont Cov:	0.7
Cap ALE Cov:	0.2
OHP:	1.2
R&R:	1.25

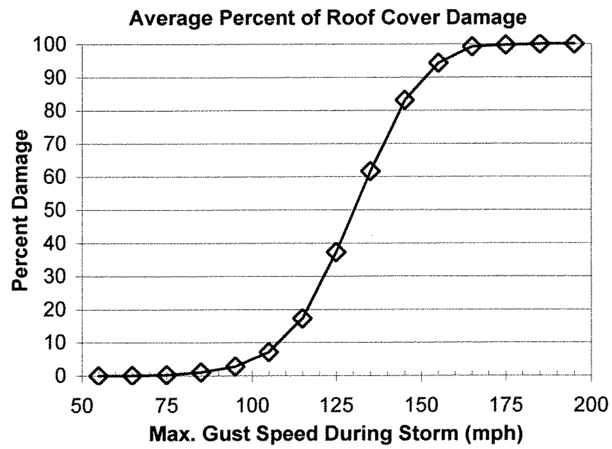


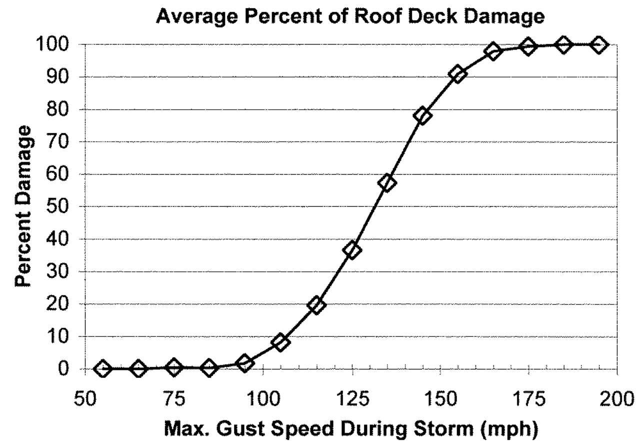
Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW1DK1PR100006C

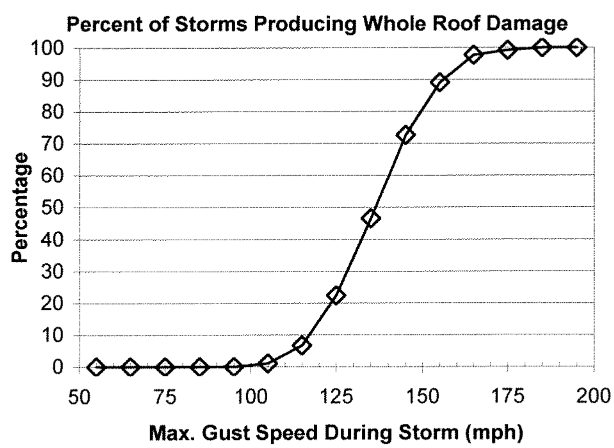


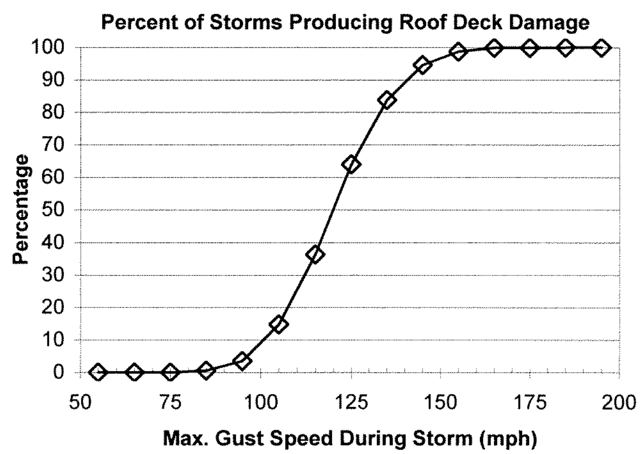
Average Physical Damage State: 0.207

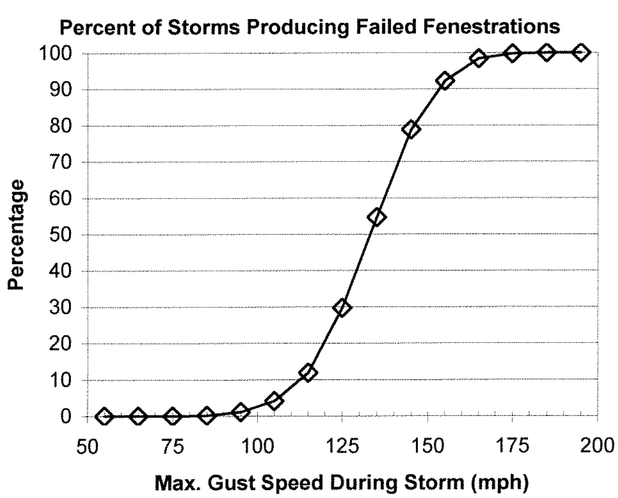


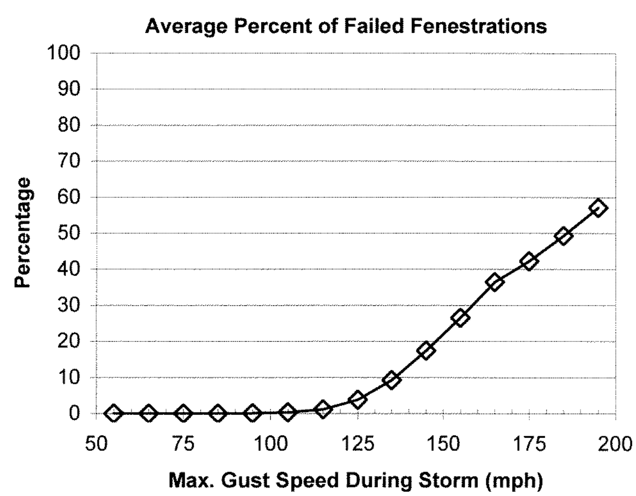

Average Percent of Roof Cover Damage
Percent Damage
Max. Gust Speed During Storm (mph)
0 10 20 30 40 50 60 70 80 90 100
50 75 100 125 150 175 200

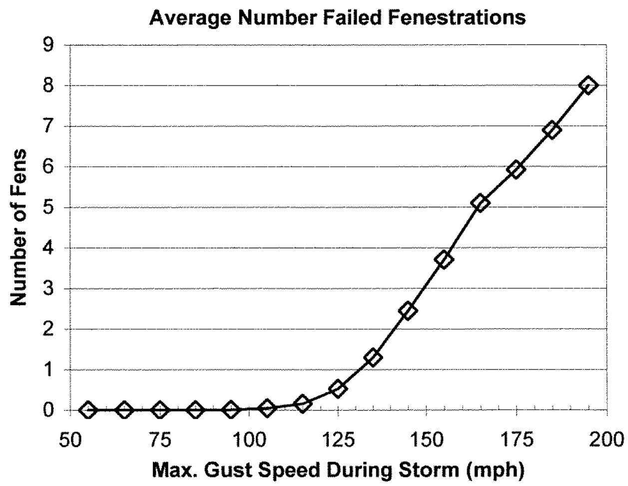

Average Percent of Roof Deck Damage
Percent Damage
Max. Gust Speed During Storm (mph)
0 10 20 30 40 50 60 70 80 90 100
50 75 100 125 150 175 200

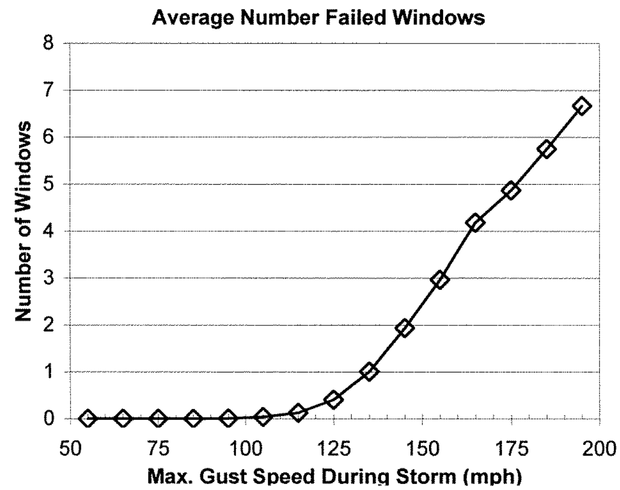

Percent of Storms Producing Whole Roof Damage
Percentage
Max. Gust Speed During Storm (mph)
0 10 20 30 40 50 60 70 80 90 100
50 75 100 125 150 175 200

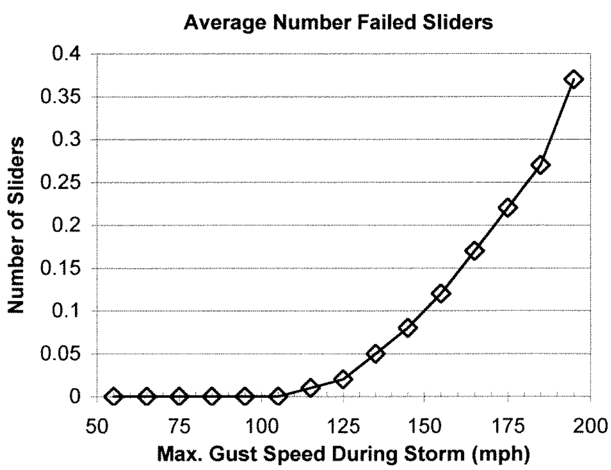

Percent of Storms Producing Roof Deck Damage
Percentage
Max. Gust Speed During Storm (mph)
0 10 20 30 40 50 60 70 80 90 100
50 75 100 125 150 175 200

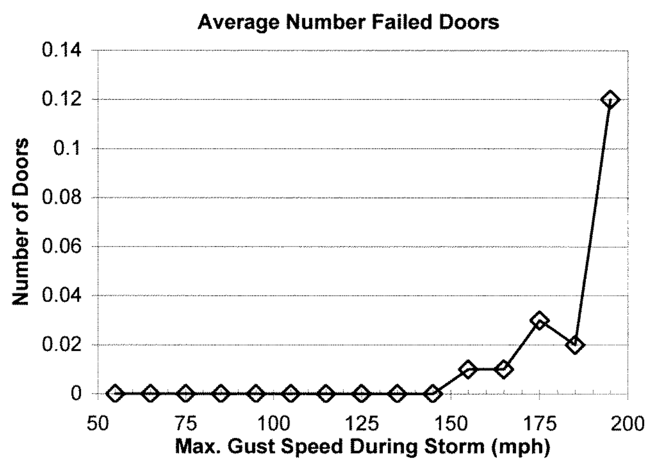

Percent of Storms Producing Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)
0 10 20 30 40 50 60 70 80 90 100
50 75 100 125 150 175 200

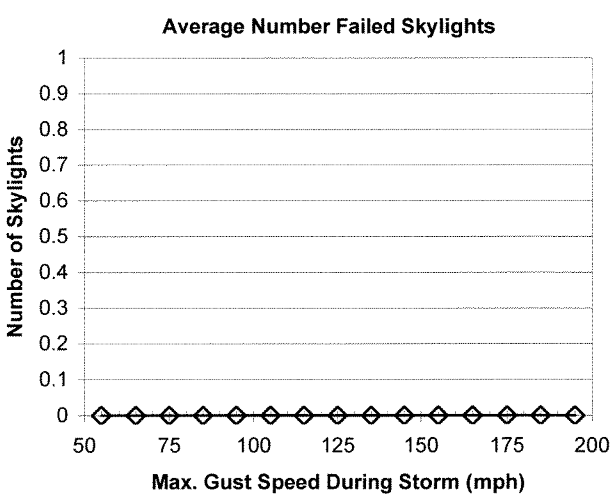

Average Percent of Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)
0 10 20 30 40 50 60 70 80 90 100
50 75 100 125 150 175 200

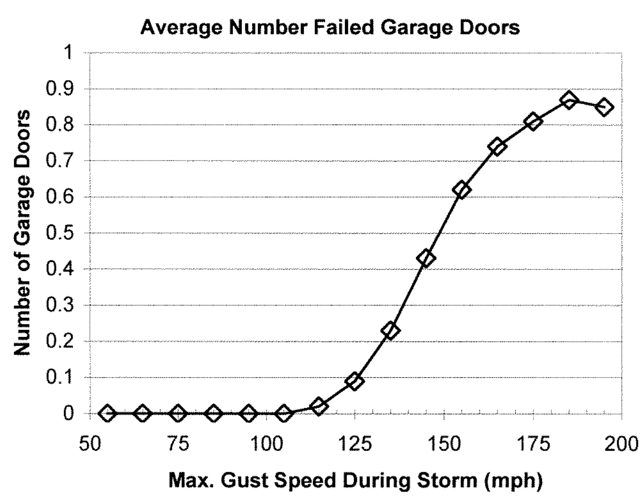

Average Number Failed Fenestrations
Number of Fens
0 1 2 3 4 5 6 7 8 9
50 75 100 125 150 175 200
Max. Gust Speed During Storm (mph)

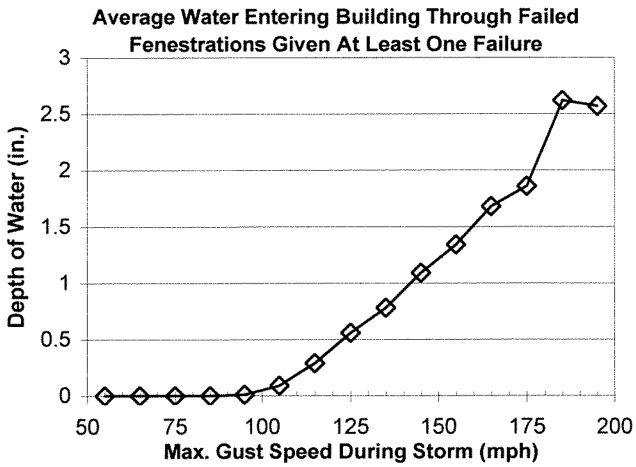

Average Number Failed Windows
Number of Windows
0 1 2 3 4 5 6 7 8
50 75 100 125 150 175 200
Max. Gust Speed During Storm (mph)

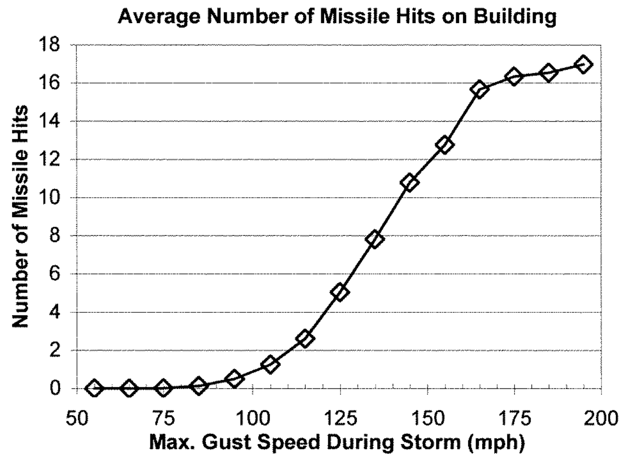

Average Number Failed Sliders
Number of Sliders
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4
50 75 100 125 150 175 200
Max. Gust Speed During Storm (mph)

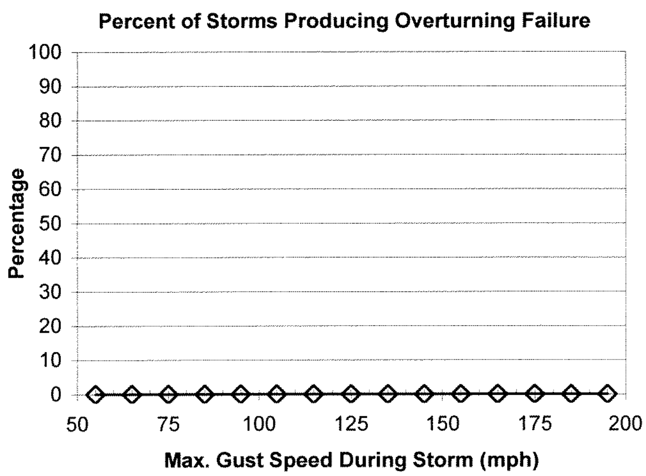

Average Number Failed Doors
Number of Doors
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14
50 75 100 125 150 175 200
Max. Gust Speed During Storm (mph)

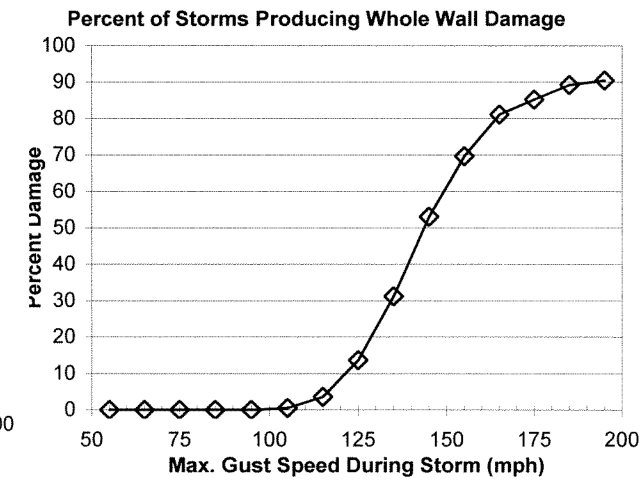

Average Number Failed Skylights
Number of Skylights
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
50 75 100 125 150 175 200
Max. Gust Speed During Storm (mph)

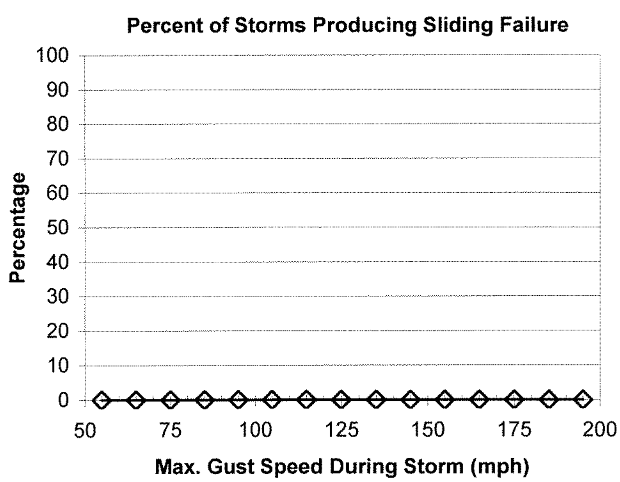

Average Number Failed Garage Doors
Number of Garage Doors
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
50 75 100 125 150 175 200
Max. Gust Speed During Storm (mph)


Average Water Entering Building Through Failed Fenestrations Given At Least One Failure
Depth of Water (in.)
Max. Gust Speed During Storm (mph)


Average Number of Missile Hits on Building
Number of Missile Hits
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Overturning Failure
Percentage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Whole Wall Damage
Percent Damage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Sliding Failure
Percentage
Max. Gust Speed During Storm (mph)

Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW2DK2PR100006C

HurReport - Single Family Residential

Building Description

Stories:	1
Primary Roof Shape:	Gable
Roof Cover:	Asphalt/Fiberglass Shingles
SWR:	No
Roof/Wall Connection:	Single Clip
Roof Deck:	Plywood
Roof Deck Attachment:	8d/06/12/06
Wall Construction:	Stick Frame

Type	*Plan*	*Roof*	*Wall*	*Fen*	*Glazing*
Area (sf)	1800	1950	1808	421	241
Percent	NA	NA	NA	23%	13%

Protection Level	*Area (sf)*	*Percent **
Annealed Glass	194	11%
Tempered Glass	47	3%

* percent of wall area for fens and percent of roof area for skylights.

Fen:	*Windows*	*Doors*	*Sliders*	*Garage*	*Skylights*
Cnt:	10	1	2	1	0

Wind Climate

Num of Year Sim: 300,000
Sim File: \DCADOI\HurLossArchive\WindClimateData\SIMW00006.dat

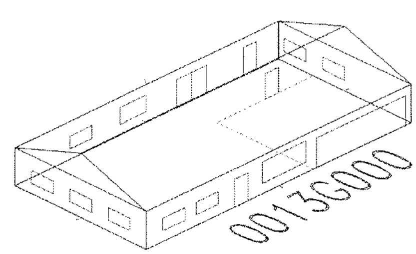
Num Sim Per Storm:	30
100 Yr Wind Speed:	112 mph
250 Yr Wind Speed:	126 mph
1000 Yr Wind Speed:	145 mph
Annual Occ. Rate:	0.54633
Latitude (deg):	29.9371
Longitude (deg):	84.3393
Orientation:	Random
Inland Distance(km):	0.2
Terrain (m):	0.03
Location:	Lighthouse Point

Cat.	Number of Storms
0	148,366
I	11,807
II	2,839
III	761
IV	119
V	6
Total	163,898

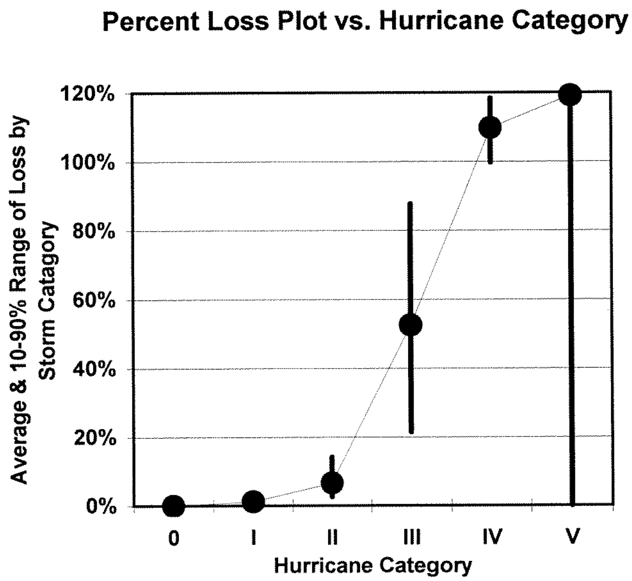
Economic Description

	Value	*Cap*
Building:	$100,000.00	1.25
Contents:	$70,000.00	1.00
ALE:	$20,000.00	1.00
Deductible:	0/2000/5000	

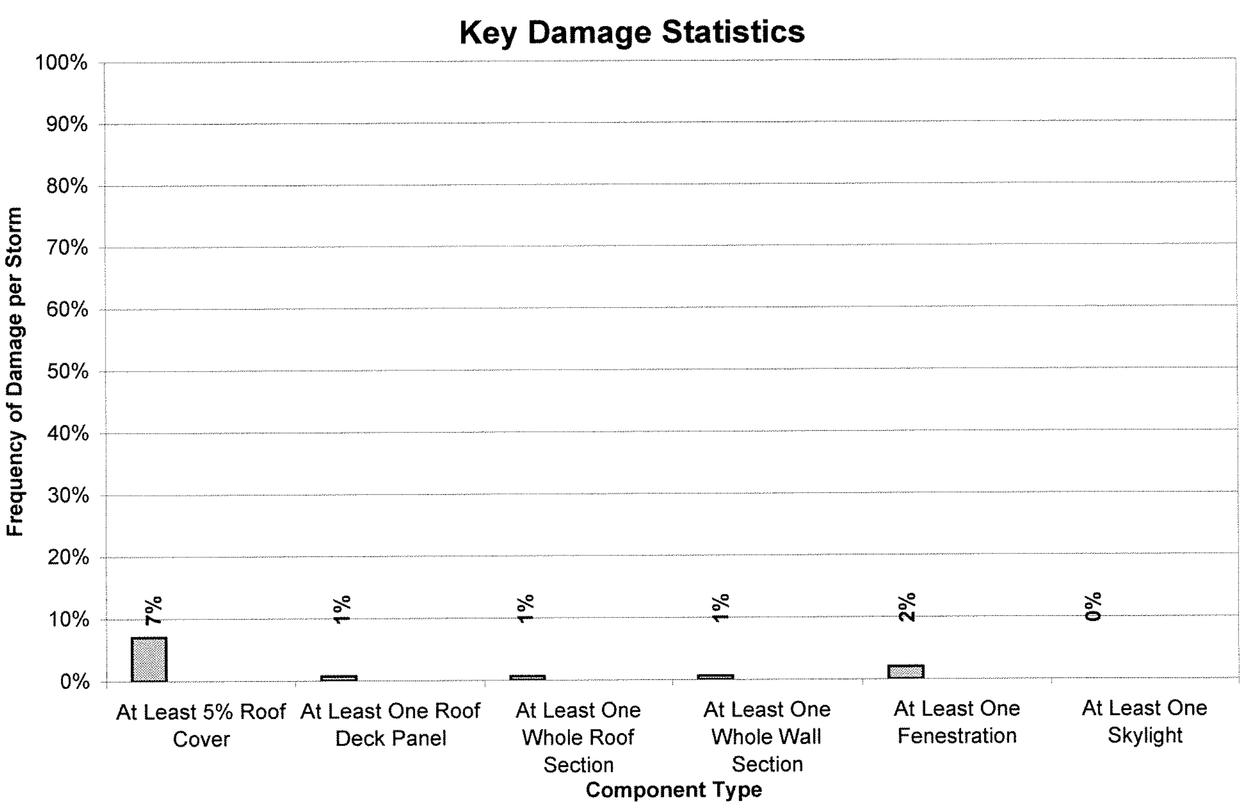
Cap Cont Cov:	0.7
Cap ALE Cov:	0.2
OHP:	1.2
R&R:	1.25

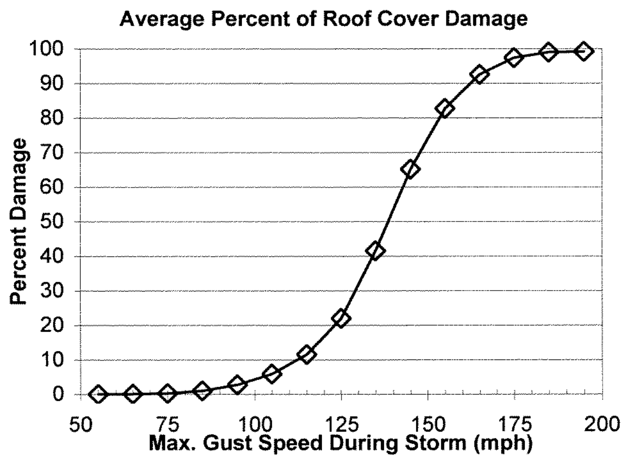


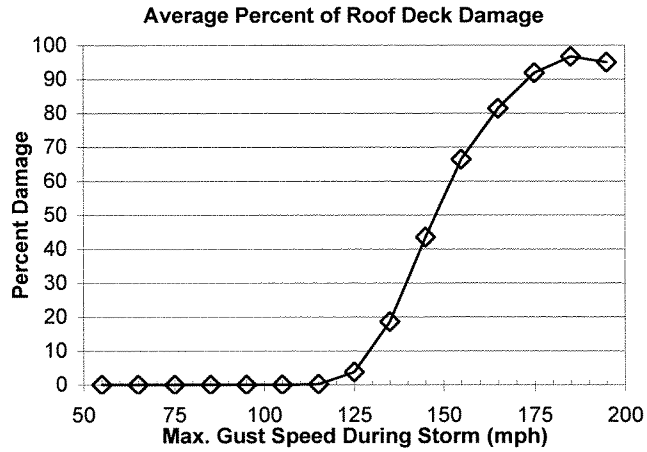
Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW2DK2PR100006C

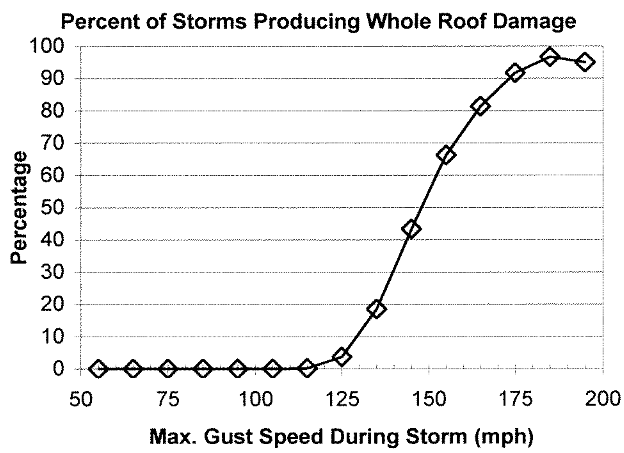


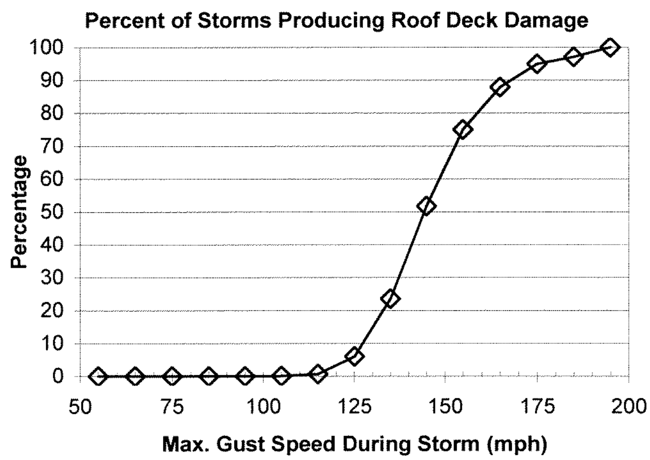
Average Physical Damage State: 0.171

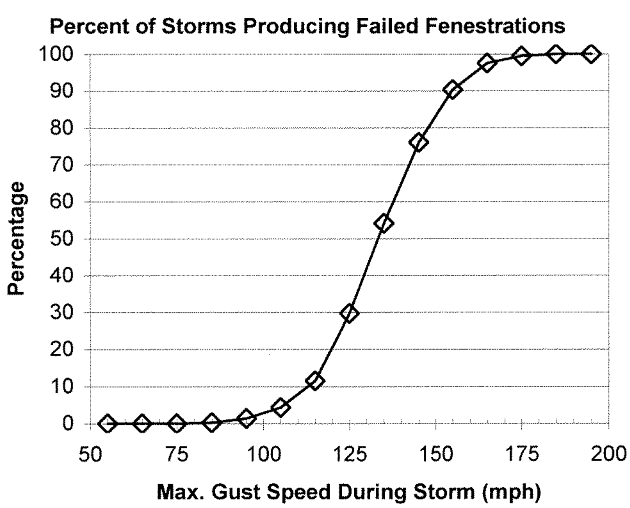


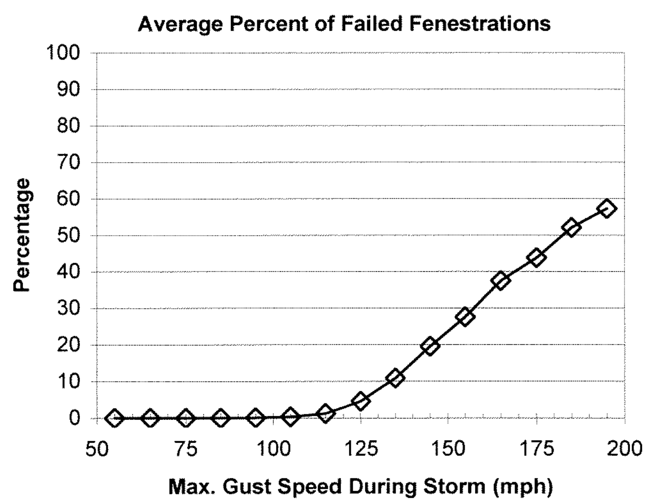

Average Percent of Roof Cover Damage
Percent Damage
Max. Gust Speed During Storm (mph)

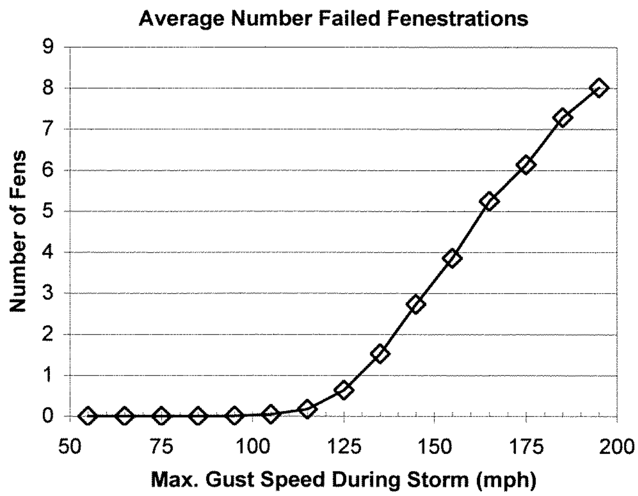

Average Percent of Roof Deck Damage
Percent Damage
Max. Gust Speed During Storm (mph)

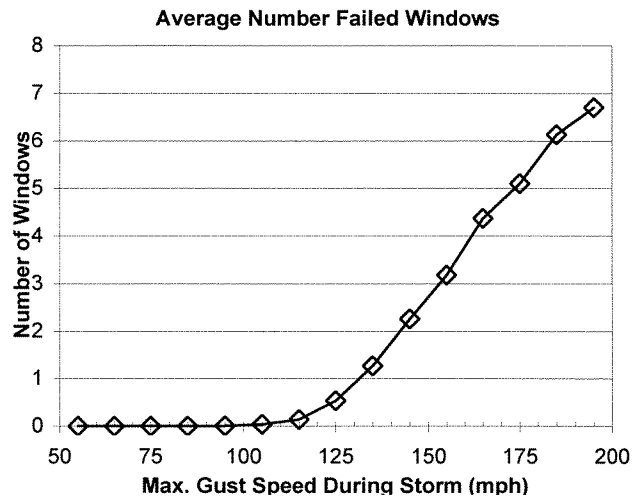

Percent of Storms Producing Whole Roof Damage
Percentage
Max. Gust Speed During Storm (mph)

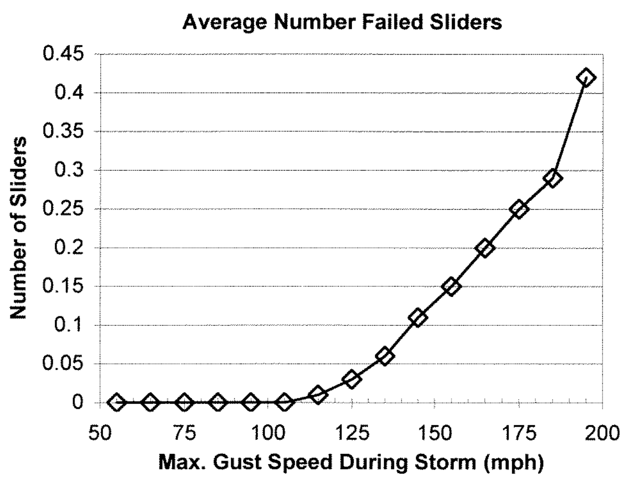

Percent of Storms Producing Roof Deck Damage
Percentage
Max. Gust Speed During Storm (mph)

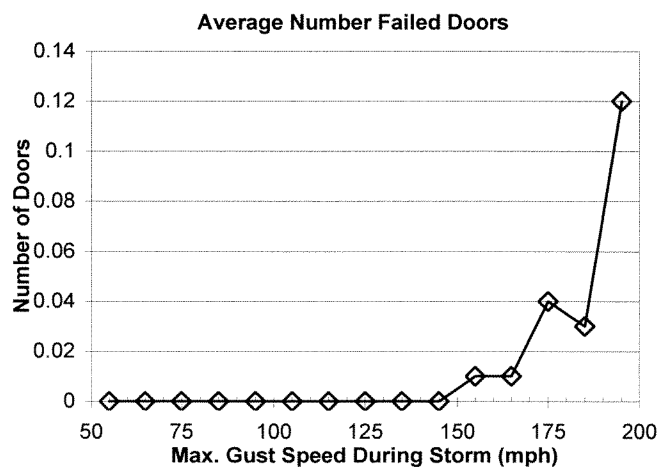

Percent of Storms Producing Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)

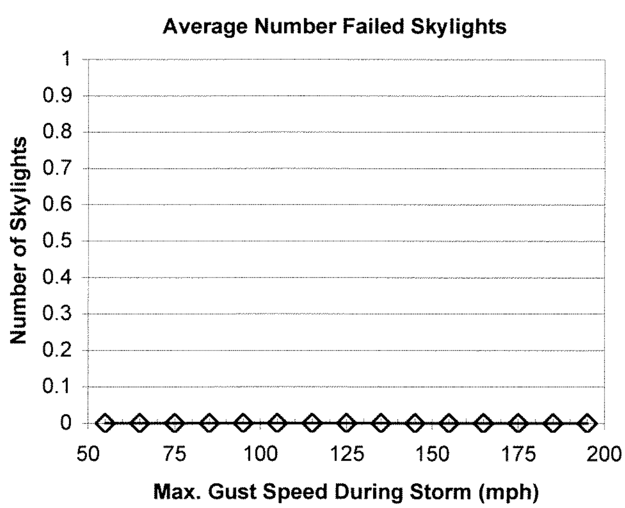

Average Percent of Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)

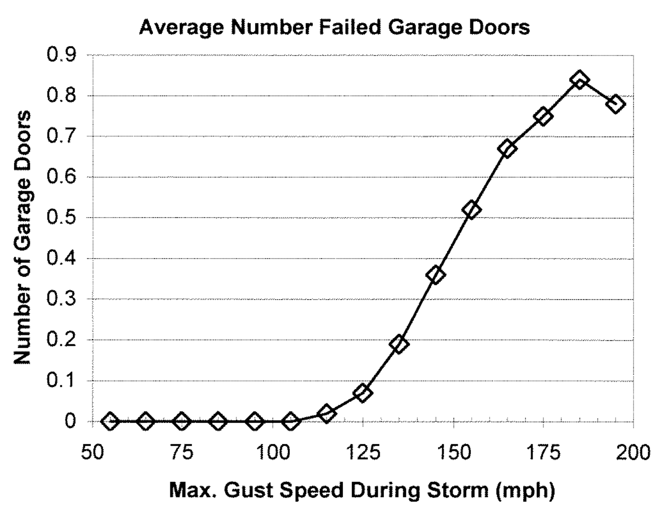

Average Number Failed Fenestrations
Number of Fens
Max. Gust Speed During Storm (mph)

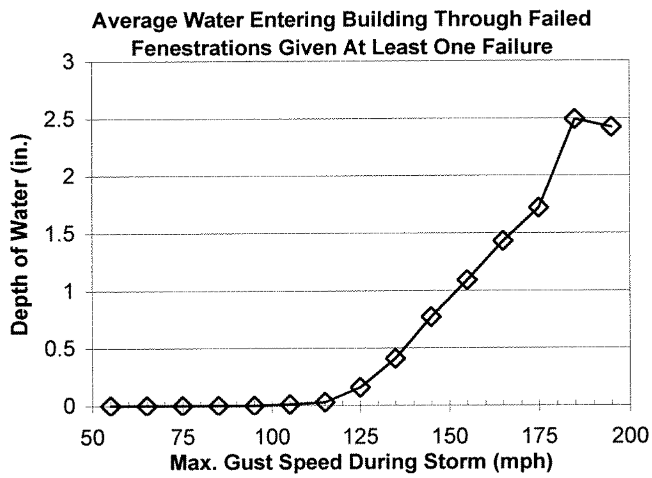

Average Number Failed Windows
Number of Windows
Max. Gust Speed During Storm (mph)

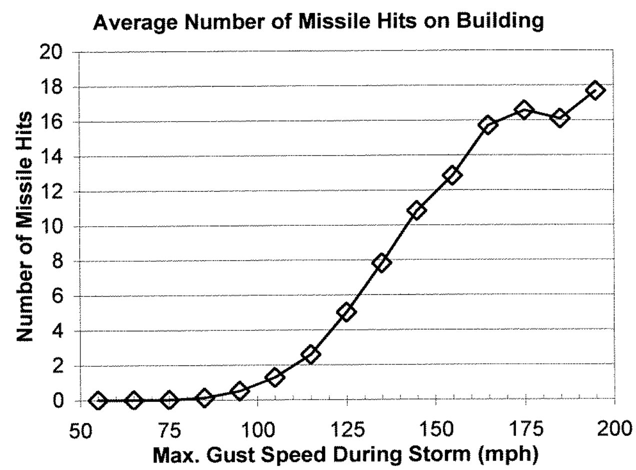

Average Number Failed Sliders
Number of Sliders
Max. Gust Speed During Storm (mph)

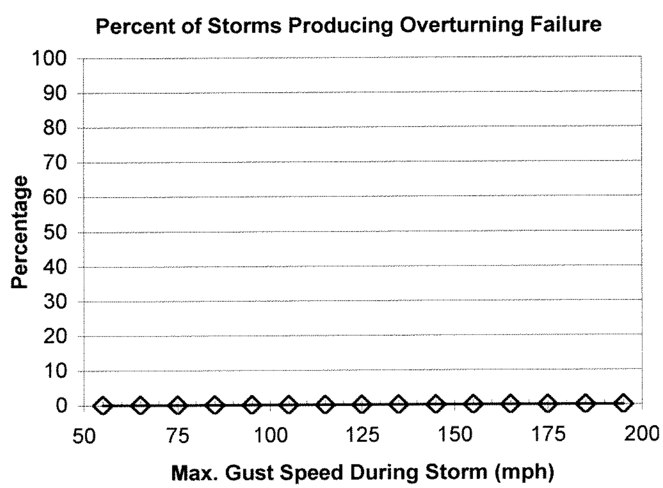

Average Number Failed Doors
Number of Doors
Max. Gust Speed During Storm (mph)

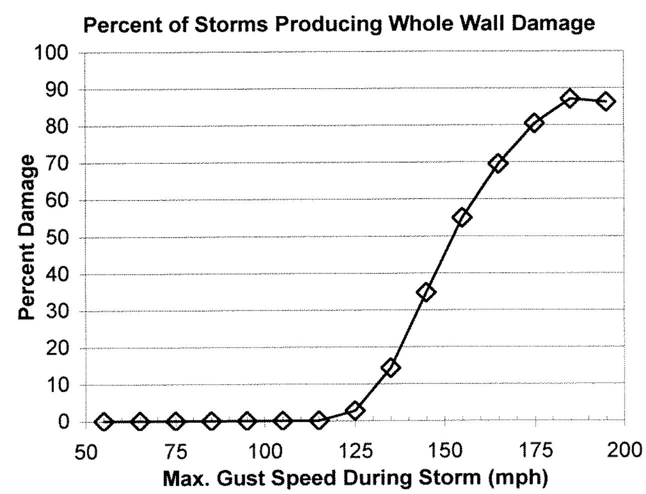

Average Number Failed Skylights
Number of Skylights
Max. Gust Speed During Storm (mph)

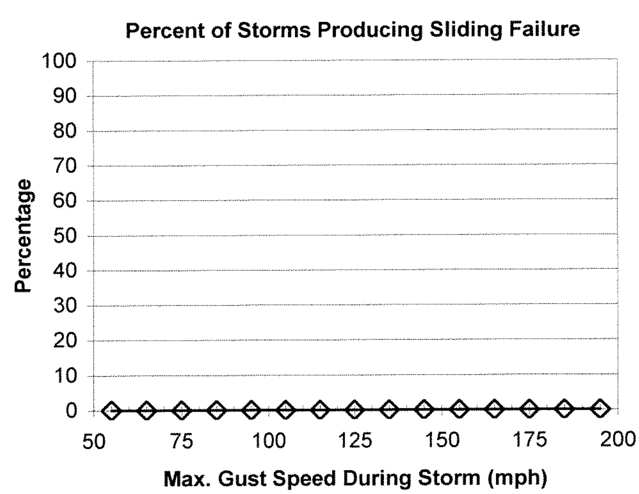

Average Number Failed Garage Doors
Number of Garage Doors
Max. Gust Speed During Storm (mph)


Average Water Entering Building Through Failed Fenestrations Given At Least One Failure
Depth of Water (in.)
Max. Gust Speed During Storm (mph)


Average Number of Missile Hits on Building
Number of Missile Hits
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Overturning Failure
Percentage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Whole Wall Damage
Percent Damage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Sliding Failure
Percentage
Max. Gust Speed During Storm (mph)

Case ID: 0013H
Dir: D:\DcaDoi2\ReportRuns\0013HRC2RW3DK3PR300006C

HurReport - Single Family Residential

Building Description

Stories:	1
Primary Roof Shape:	Hip
Roof Cover:	Asphalt/Fiberglass Shingles
SWR:	No
Roof/Wall Connection:	One-side Wrap
Roof Deck:	Plywood
Roof Deck Attachment:	8d/06/06/04
Wall Construction:	Stick Frame

Type	*Plan*	*Roof*	*Wall*	*Fen*	*Glazing*
Area (sf)	1800	1950	1620	421	241
Percent	NA	NA	NA	26%	15%

Protection Level	***Area** (sf)*	***Percent ****
Hurricane Shutter	241	15%

* percent of wall area for fens and percent of roof area for skylights.

Fen:	*Windows*	*Doors*	*Sliders*	*Garage*	*Skylights*
Cnt:	10	1	2	1	0

Wind Climate

Num of Year Sim: 300,000
Sim File: \DCADOI\HurLossArchive\WindClimateData\SIMW00006.dat

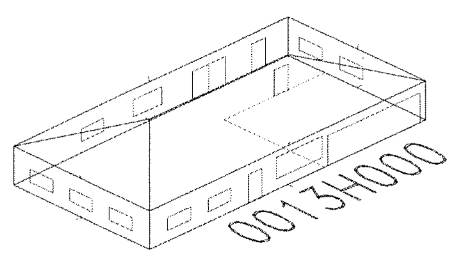
Num Sim Per Storm:	30
100 Yr Wind Speed:	112 mph
250 Yr Wind Speed:	126 mph
1000 Yr Wind Speed:	145 mph
Annual Occ. Rate:	0.54633
Latitude (deg):	29.9371
Longitude (deg):	84.3393
Orientation:	Random
Inland Distance(km):	0.2
Terrain(m):	0.03
Location:	Lighthouse Point

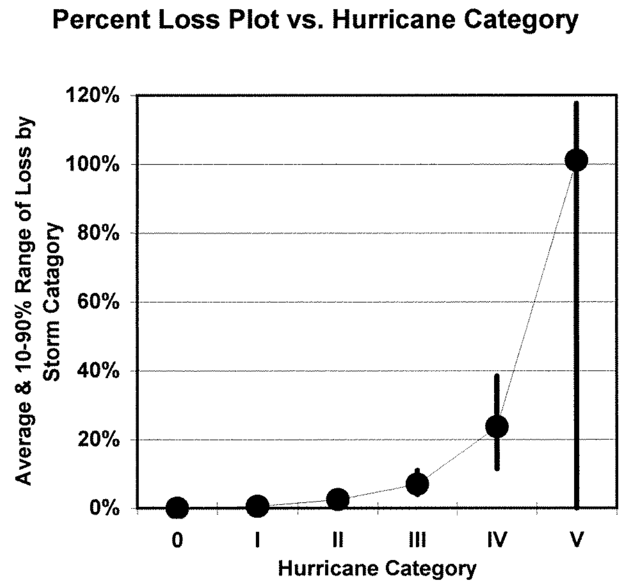
Cat.	Number of Storms
0	148,366
I	11,807
II	2,839
III	761
IV	119
V	6
Total	163,898

Economic Description

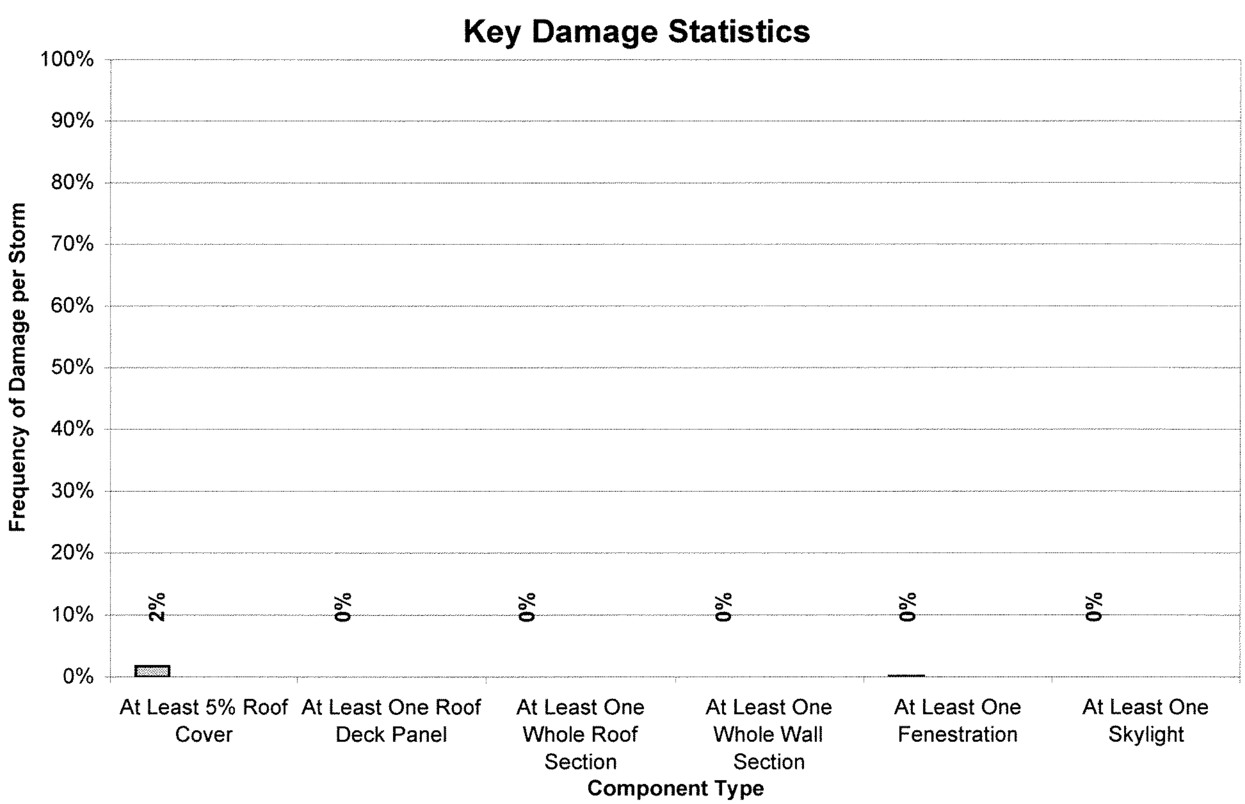
	Value	*Cap*
Building:	$105,000.00	1.25
Contents:	$73,500.00	1.00
ALE:	$21,000.00	1.00
Deductible:	0/2100/5250	

Cap Cont Cov:	0.7
Cap ALE Cov:	0.2
OHP:	1.2
R&R:	1.25

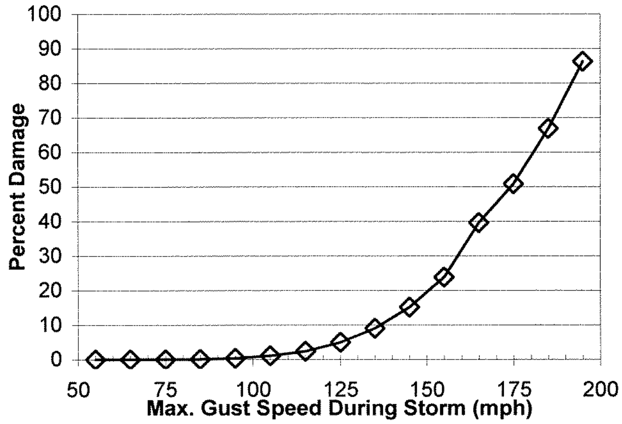




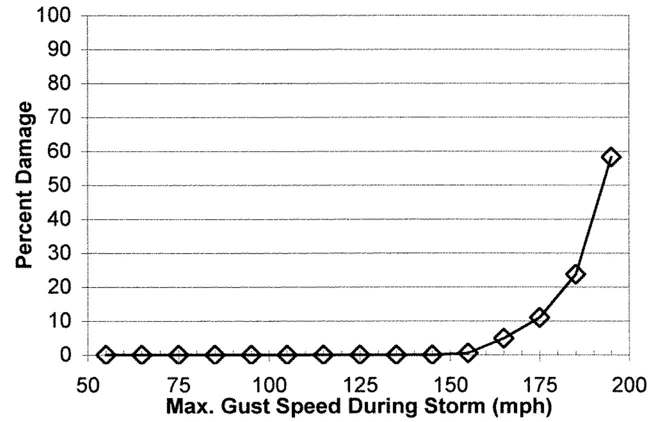
Average Physical Damage State: 0.043



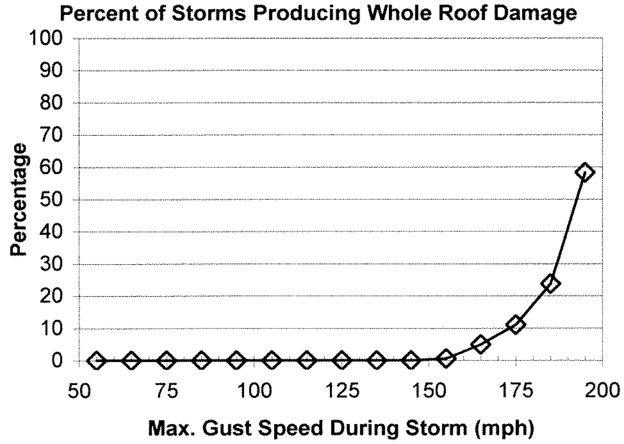
Average Percent of Roof Cover Damage



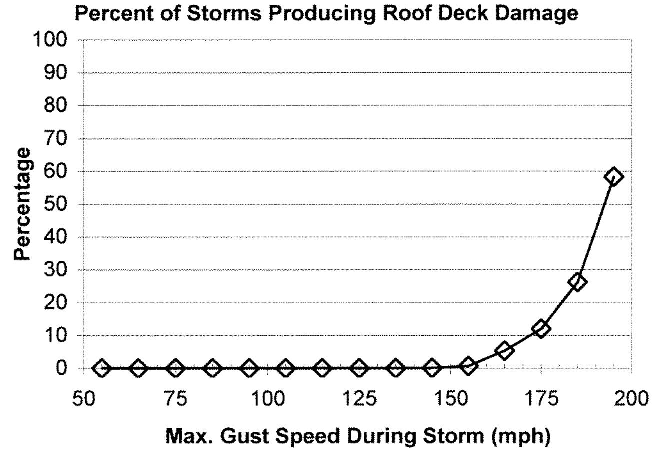
Average Percent of Roof Deck Damage



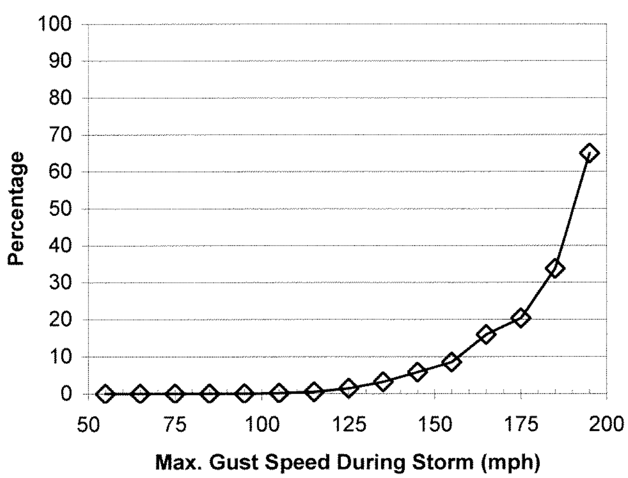
Percent of Storms Producing Whole Roof Damage



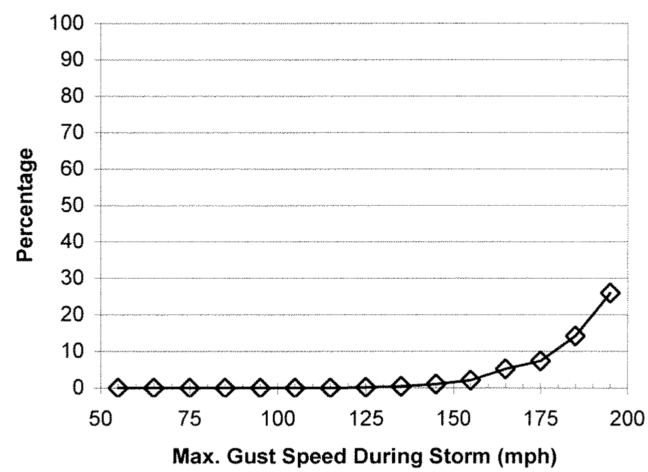
Percent of Storms Producing Roof Deck Damage

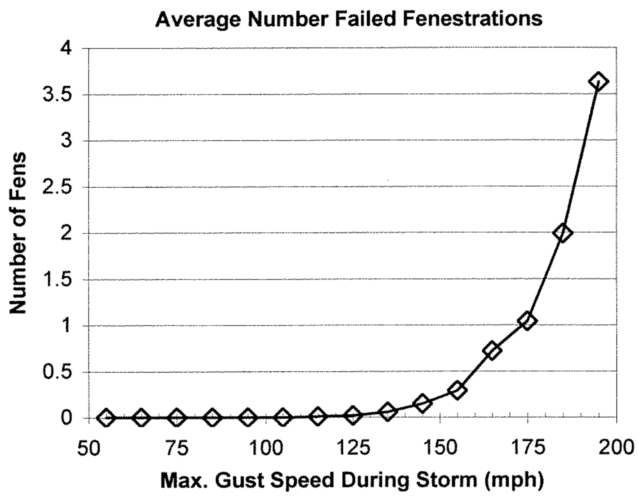


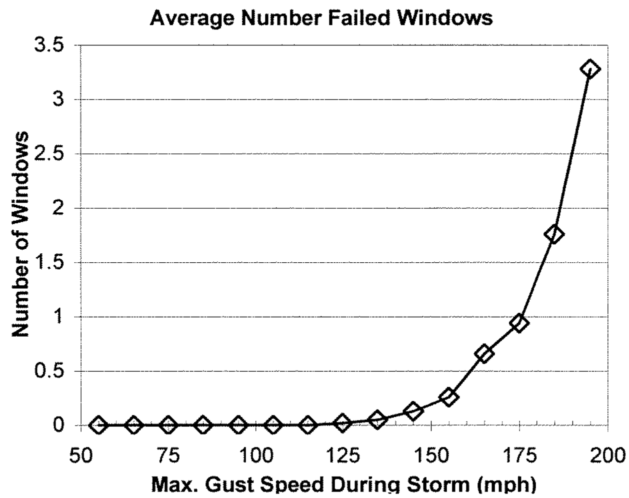
Percent of Storms Producing Failed Fenestrations

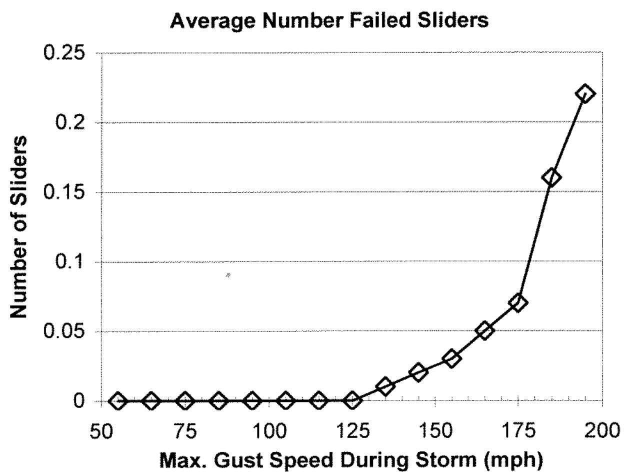


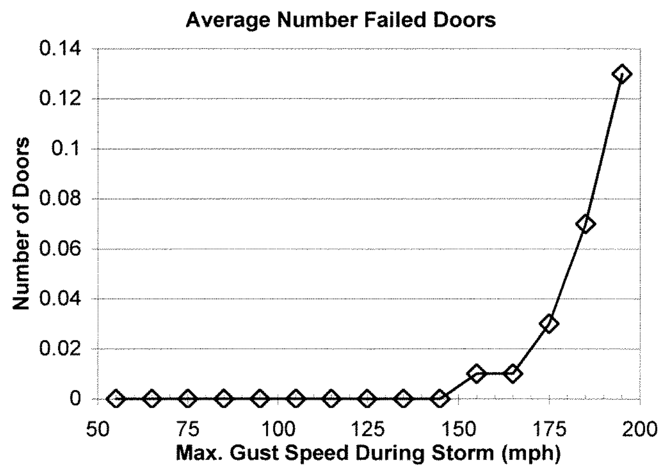
Average Percent of Failed Fenestrations

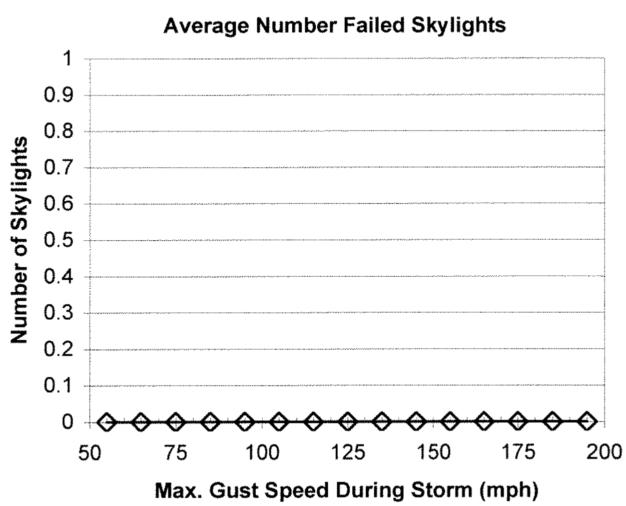


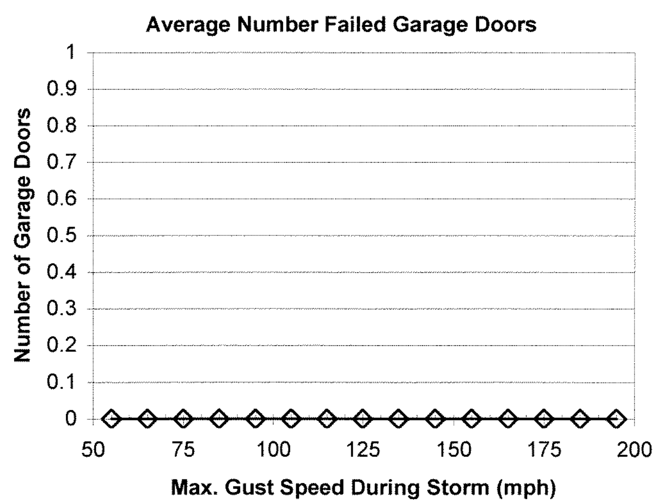

Average Number Failed Fenestrations
Number of Fens
Max. Gust Speed During Storm (mph)


Average Number Failed Windows
Number of Windows
Max. Gust Speed During Storm (mph)

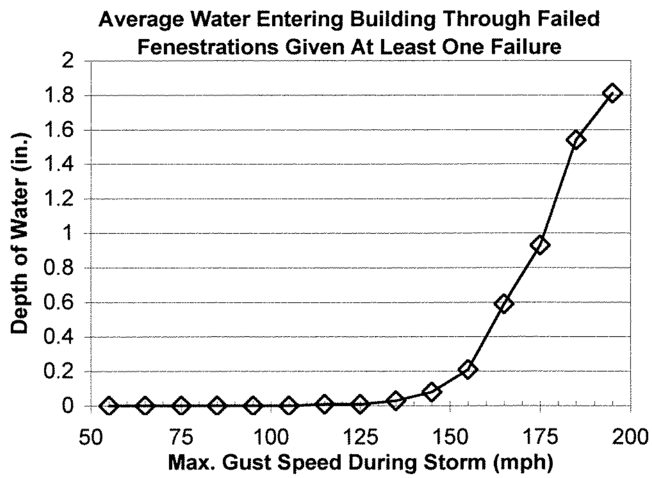

Average Number Failed Sliders
Number of Sliders
Max. Gust Speed During Storm (mph)

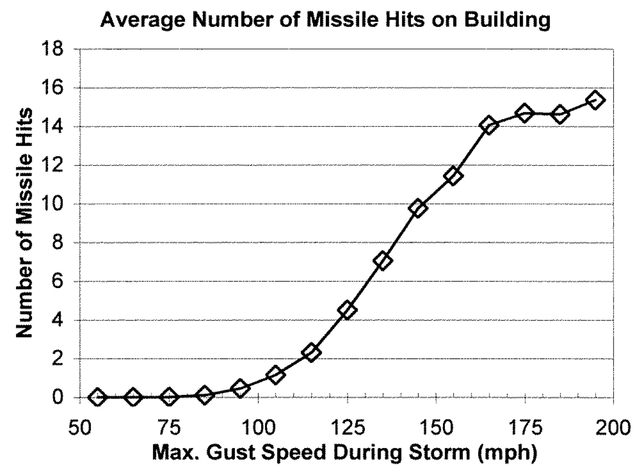

Average Number Failed Doors
Number of Doors
Max. Gust Speed During Storm (mph)

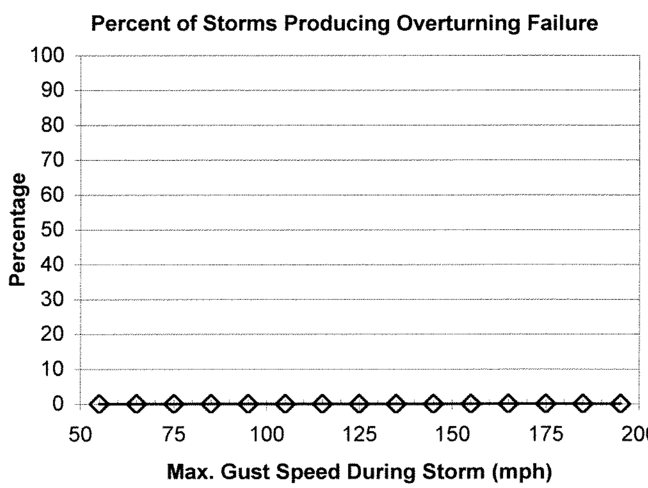

Average Number Failed Skylights
Number of Skylights
Max. Gust Speed During Storm (mph)

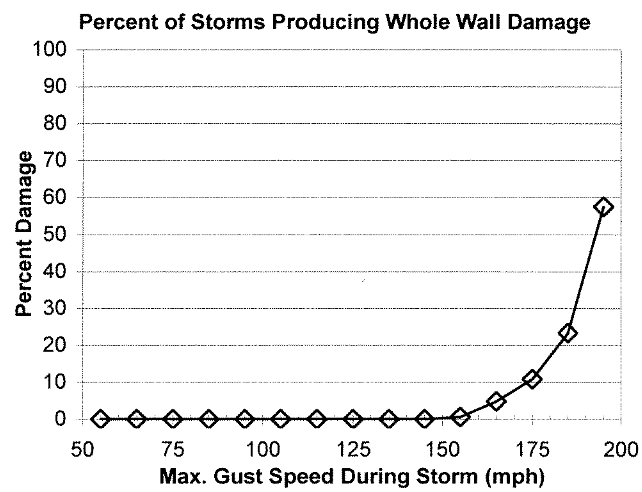

Average Number Failed Garage Doors
Number of Garage Doors
Max. Gust Speed During Storm (mph)

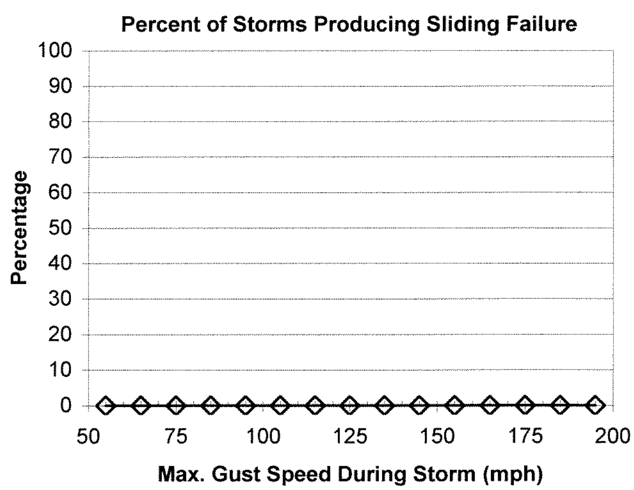
Case ID: 0013H
Dir: D:\DcaDoi2\ReportRuns\0013HRC2RW3DK3PR300006C











Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW1DK1PR100013C

HurReport - Single Family Residential

Building Description

Stories:	1
Primary Roof Shape:	Gable
Roof Cover:	Asphalt/Fiberglass Shingles
SWR:	No
Roof/Wall Connection:	Toe Nail
Roof Deck:	Plywood
Roof Deck Attachment:	6d/06/12/06
Wall Construction:	Stick Frame

Type	*Plan*	*Roof*	*Wall*	*Fen*	*Glazing*
Area (sf)	1800	1950	1808	421	241
Percent	NA	NA	NA	23%	13%

Protection Level	*Area (sf)*	*Percent **
Annealed Glass	194	11%
Tempered Glass	47	3%

* percent of wall area for fens and percent of roof area for skylights.

Fen:	*Windows*	*Doors*	*Sliders*	*Garage*	*Skylights*
Cnt:	10	1	2	1	0

Wind Climate

Num of Year Sim: 300,000
Sim File: \DCADOI\HurLossArchive\WindClimateData\SIMW00013.dat

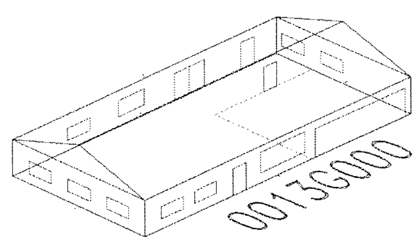
Num Sim Per Storm:	30
100 Yr Wind Speed:	142 mph
250 Yr Wind Speed:	159 mph
1000 Yr Wind Speed:	180 mph
Annual Occ. Rate:	0.57346
Latitude (deg):	25.7757
Longitude (deg):	80.2109
Orientation:	Random
Inland Distance(km):	2.5
Terrain (m):	0.03
Location:	Miami

Cat.	Number of Storms
0	143,365
I	16,302
II	7,150
III	3,794
IV	1,310
V	114
Total	172,035

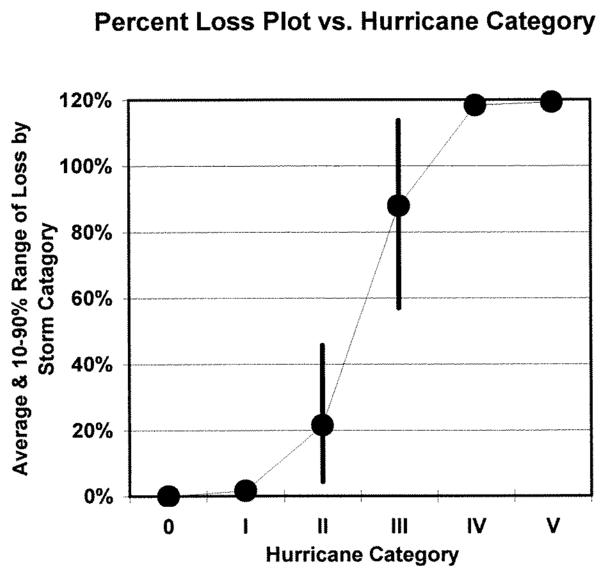
Economic Description

	Value	*Cap*
Building:	$100,000.00	1.25
Contents:	$70,000.00	1.00
ALE:	$20,000.00	1.00
Deductible:	0/2000/5000	

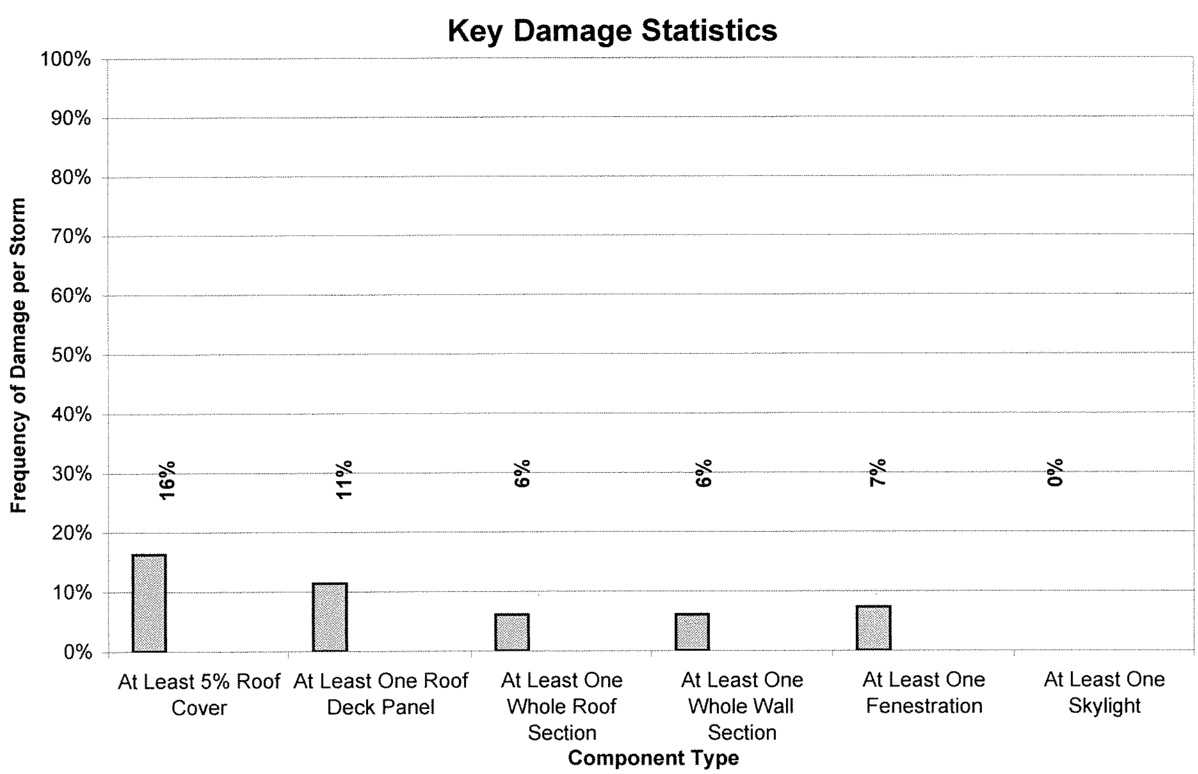
Cap Cont Cov:	0.7
Cap ALE Cov:	0.2
OHP:	1.2
R&R:	1.25

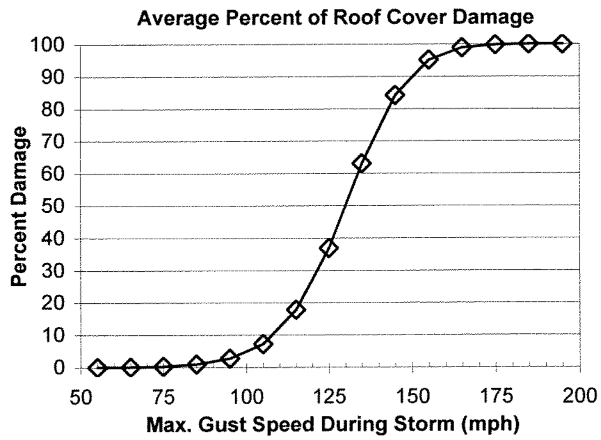


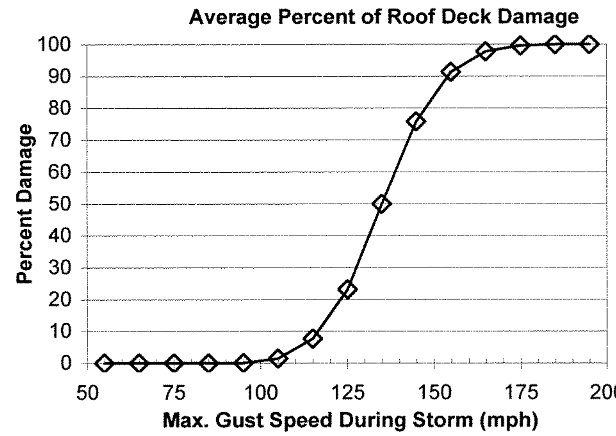
Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW1DK1PR100013C

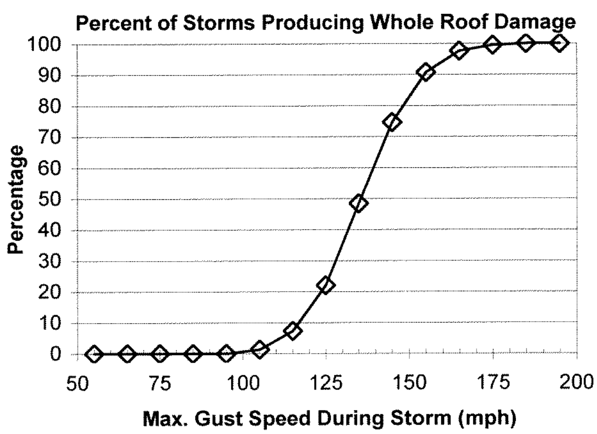


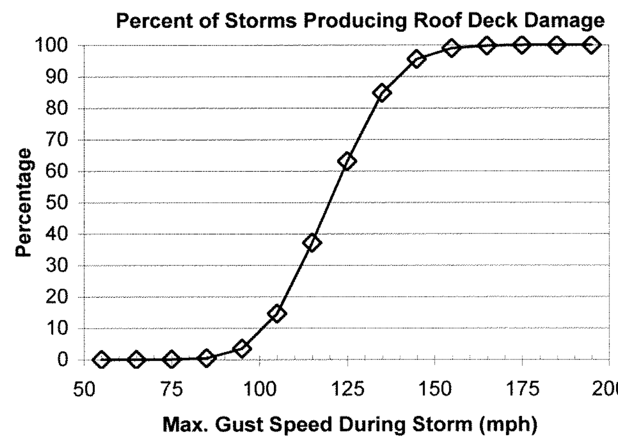
Average Physical Damage State: 0.5

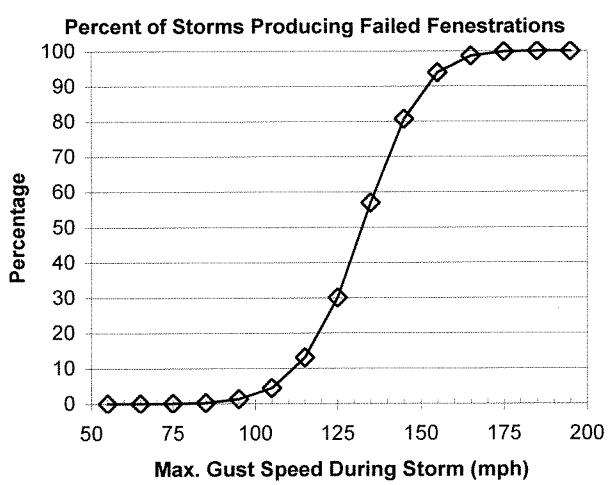


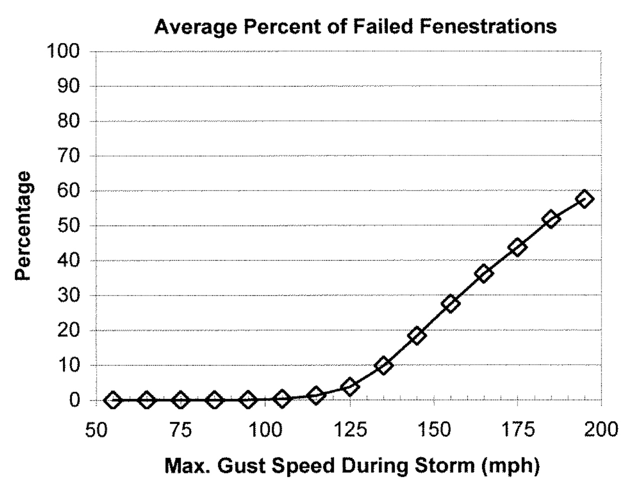

Average Percent of Roof Cover Damage
Percent Damage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)


Average Percent of Roof Deck Damage
Percent Damage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)

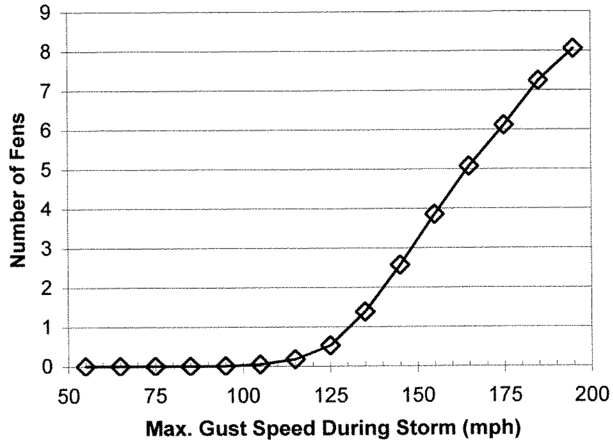

Percent of Storms Producing Whole Roof Damage
Percentage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Roof Deck Damage
Percentage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)

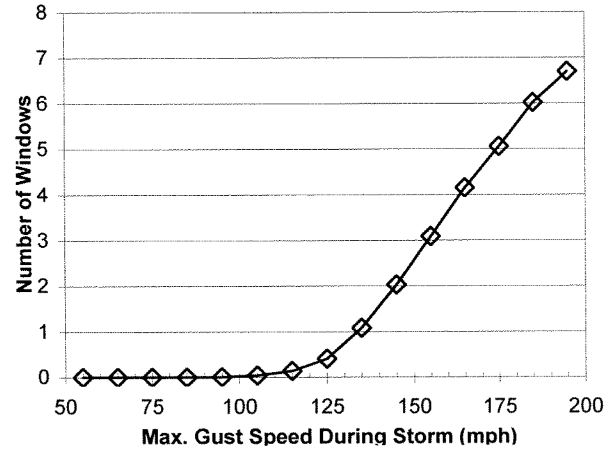

Percent of Storms Producing Failed Fenestrations
Percentage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)


Average Percent of Failed Fenestrations
Percentage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)

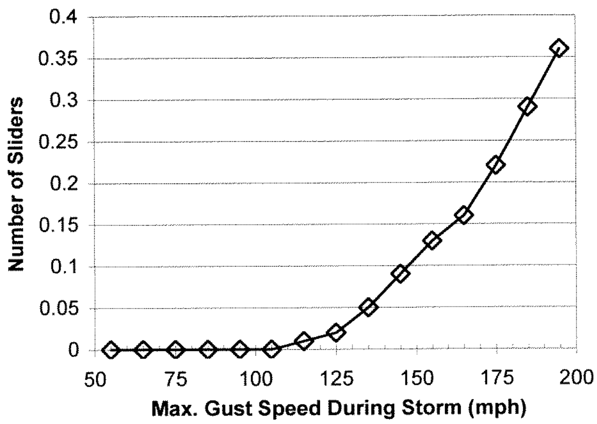
Average Number Failed Fenestrations



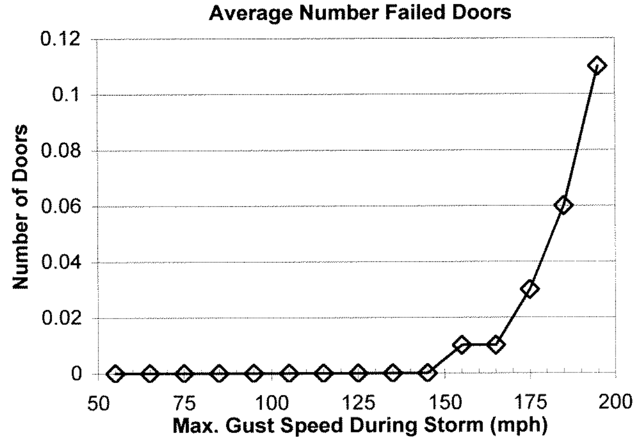
Average Number Failed Windows



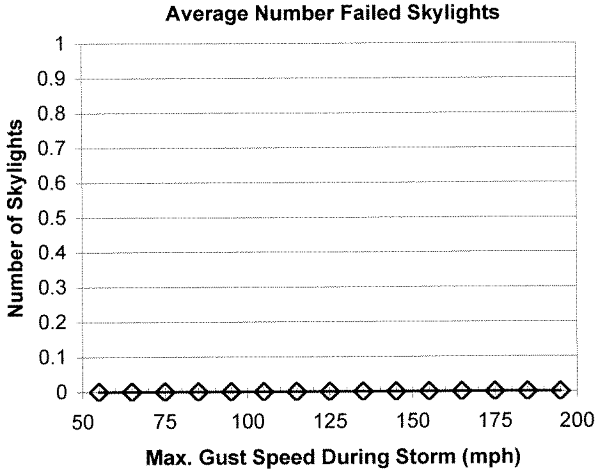
Average Number Failed Sliders



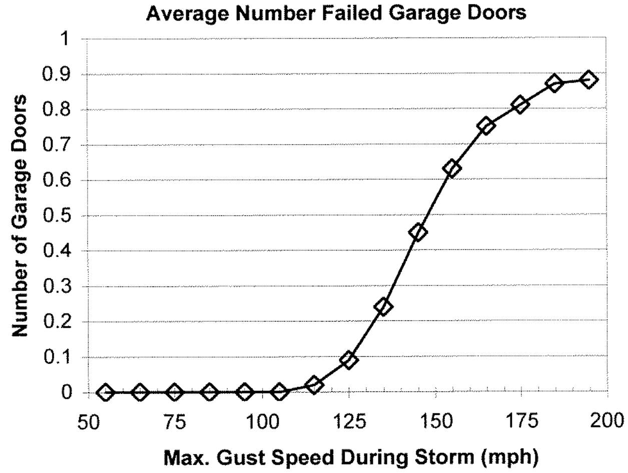
Average Number Failed Doors

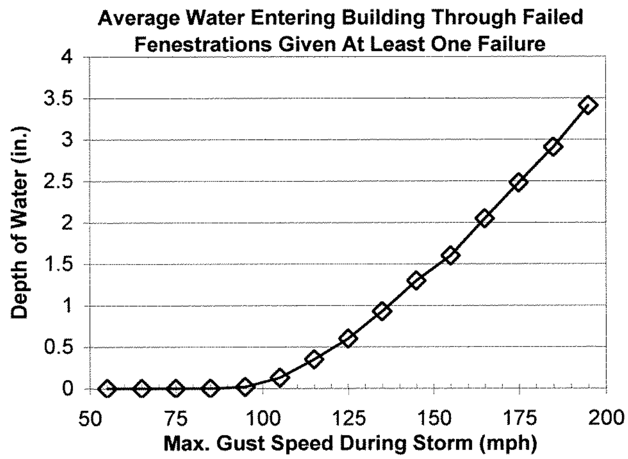


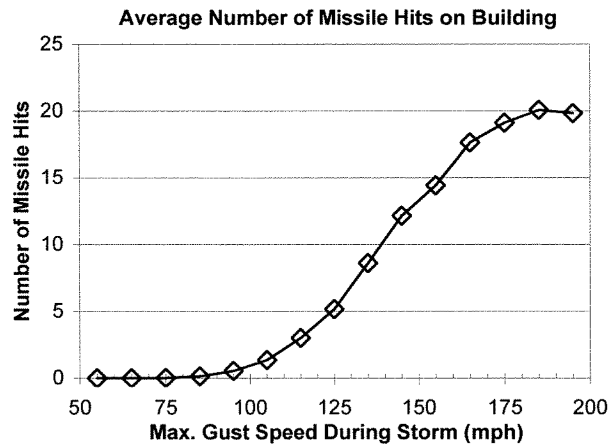
Average Number Failed Skylights

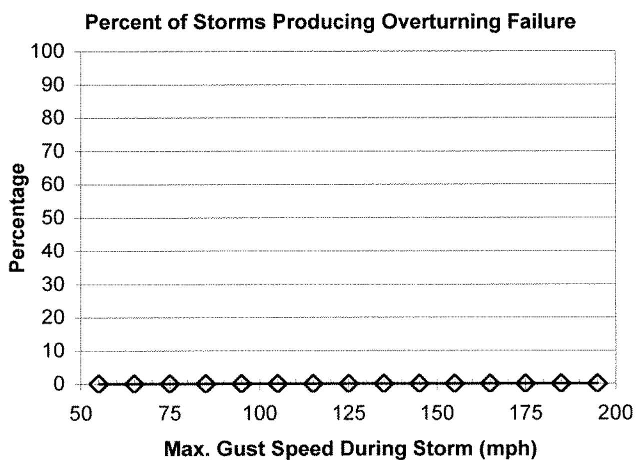


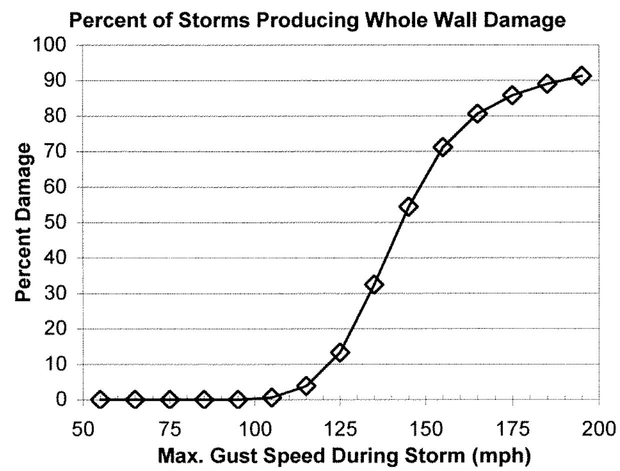
Average Number Failed Garage Doors

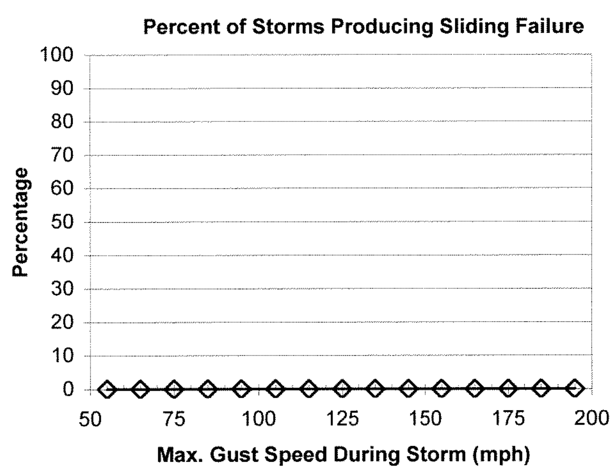



Average Water Entering Building Through Failed Fenestrations Given At Least One Failure
Depth of Water (in.)
Max. Gust Speed During Storm (mph)


Average Number of Missile Hits on Building
Number of Missile Hits
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Overturning Failure
Percentage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Whole Wall Damage
Percent Damage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Sliding Failure
Percentage
Max. Gust Speed During Storm (mph)

Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW2DK2PR100013C

HurReport - Single Family Residential

Building Description

Stories:	1
Primary Roof Shape:	Gable
Roof Cover:	Asphalt/Fiberglass Shingles
SWR:	No
Roof/Wall Connection:	Single Clip
Roof Deck:	Plywood
Roof Deck Attachment:	8d/06/12/06
Wall Construction:	Stick Frame

Type	*Plan*	*Roof*	*Wall*	*Fen*	*Glazing*
Area (sf)	1800	1950	1808	421	241
Percent	NA	NA	NA	23%	13%

Protection Level	*Area (sf)*	*Percent **
Annealed Glass	194	11%
Tempered Glass	47	3%

* percent of wall area for fens and percent of roof area for skylights.

Fen:	Windows	Doors	Sliders	Garage	Skylights
Cnt:	10	1	2	1	0

Wind Climate

Num of Year Sim: 300,000
Sim File: \DCADOI\HurLossArchive\WindClimateData\SIMW00013.dat

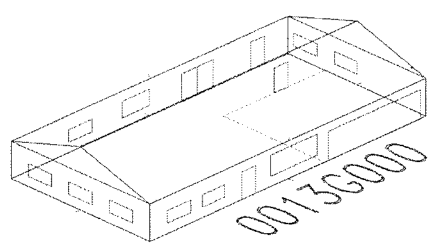
Num Sim Per Storm:	30
100 Yr Wind Speed:	142 mph
250 Yr Wind Speed:	159 mph
1000 Yr Wind Speed:	180 mph
Annual Occ. Rate:	0.57346
Latitude (deg):	25.7757
Longitude (deg):	80.2109
Orientation:	Random
Inland Distance(km):	2.5
Terrain(m):	0.03
Location:	Miami

Cat.	Number of Storms
0	143,365
I	16,302
II	7,150
III	3,794
IV	1,310
V	114
Total	172,035

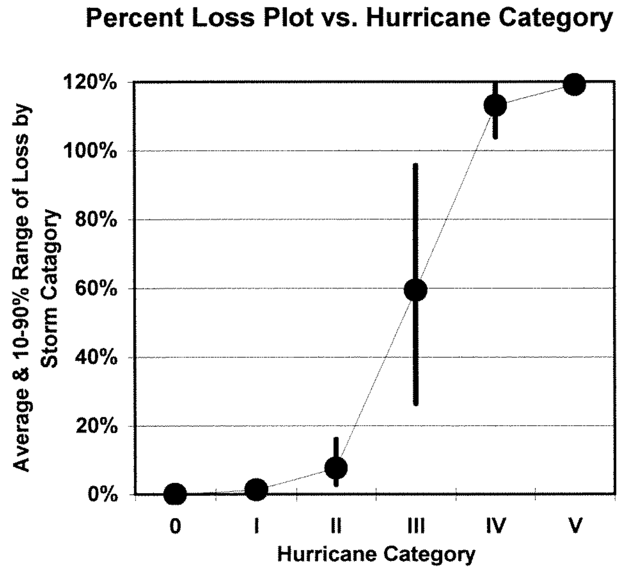
Economic Description

	Value	*Cap*
Building:	$100,000.00	1.25
Contents:	$70,000.00	1.00
ALE:	$20,000.00	1.00
Deductible:	0/2000/5000	

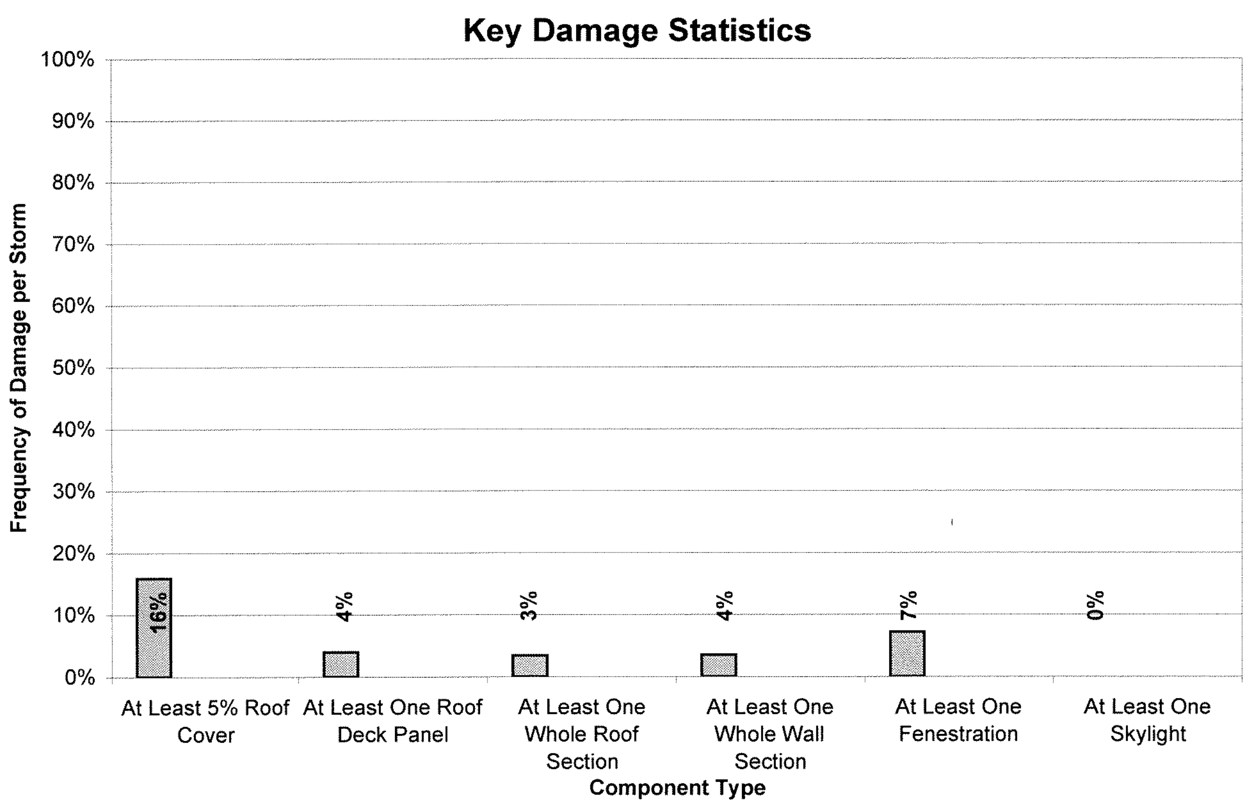
Cap Cont Cov:	0.7
Cap ALE Cov:	0.2
OHP:	1.2
R&R:	1.25

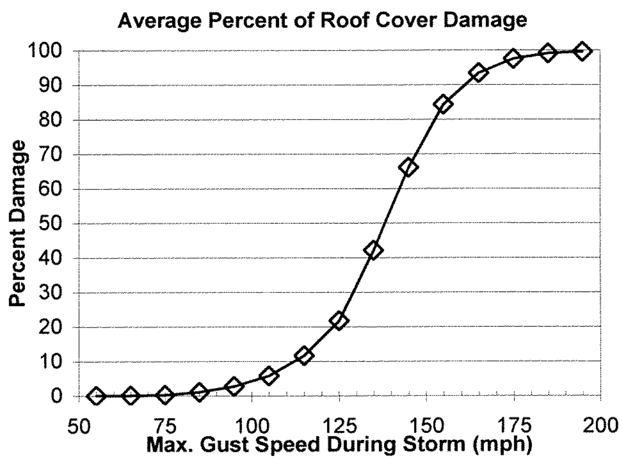


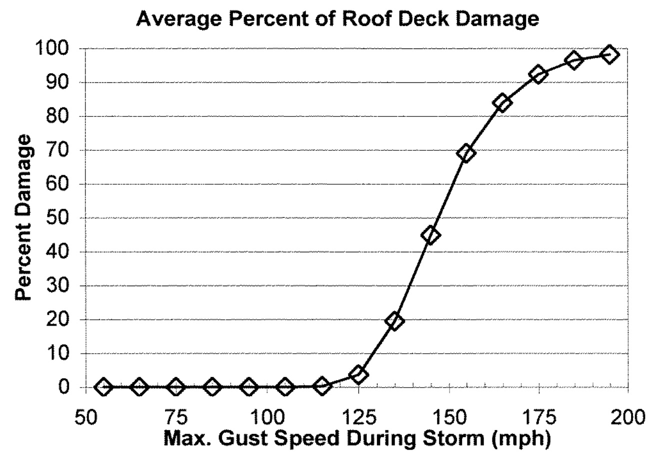
Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW2DK2PR100013C

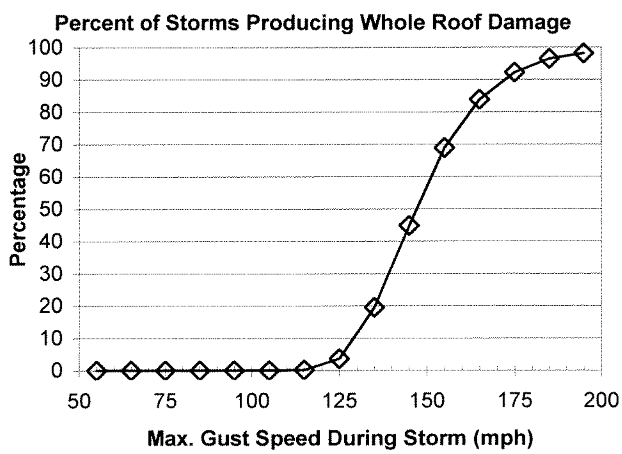


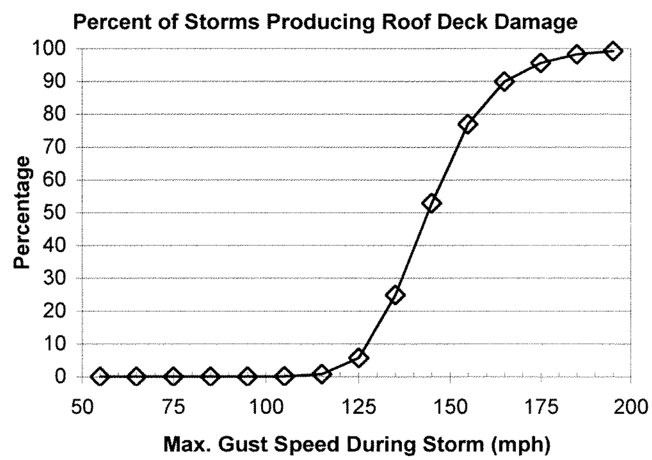
Average Physical Damage State: 0.42

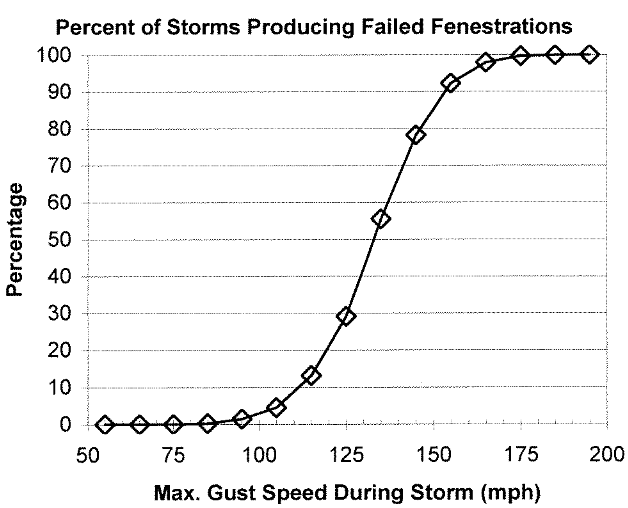


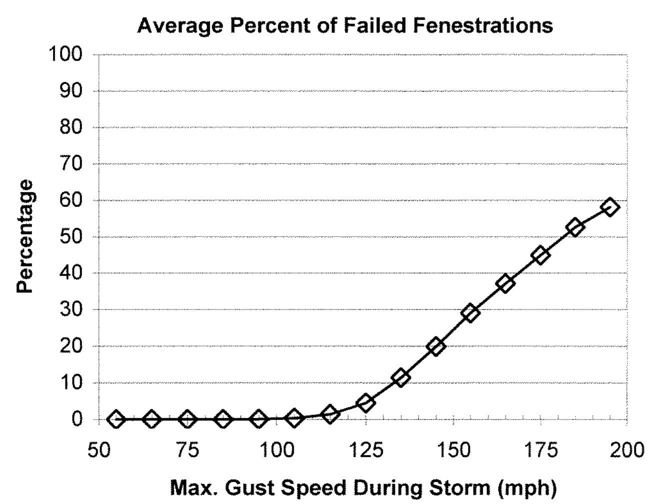

Average Percent of Roof Cover Damage
Percent Damage
Max. Gust Speed During Storm (mph)


Average Percent of Roof Deck Damage
Percent Damage
Max. Gust Speed During Storm (mph)

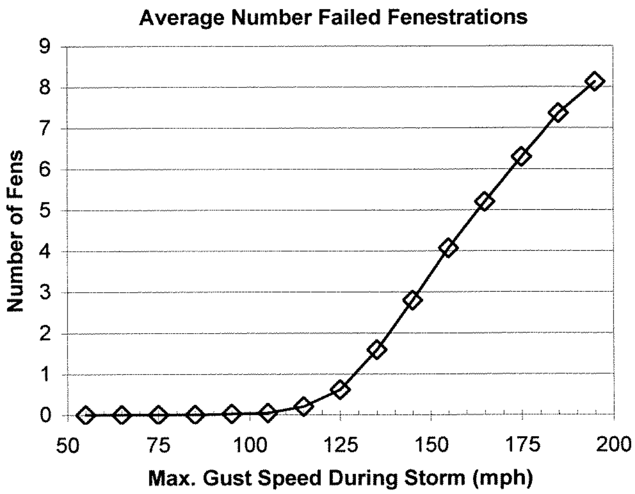

Percent of Storms Producing Whole Roof Damage
Percentage
Max. Gust Speed During Storm (mph)

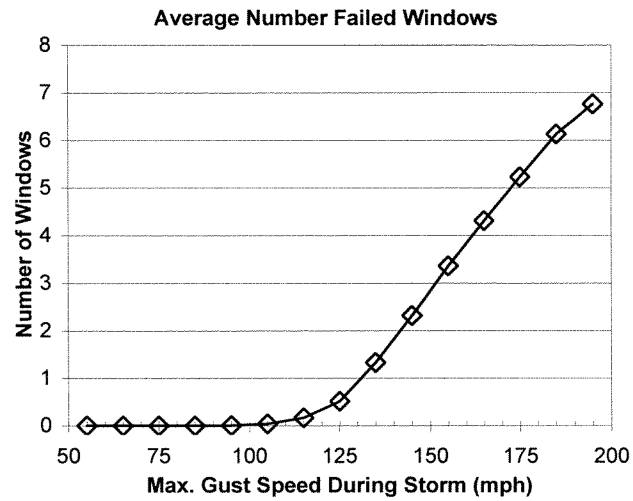

Percent of Storms Producing Roof Deck Damage
Percentage
Max. Gust Speed During Storm (mph)

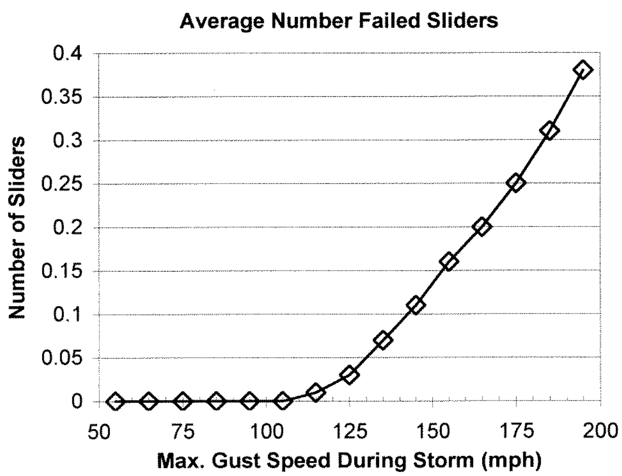

Percent of Storms Producing Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)

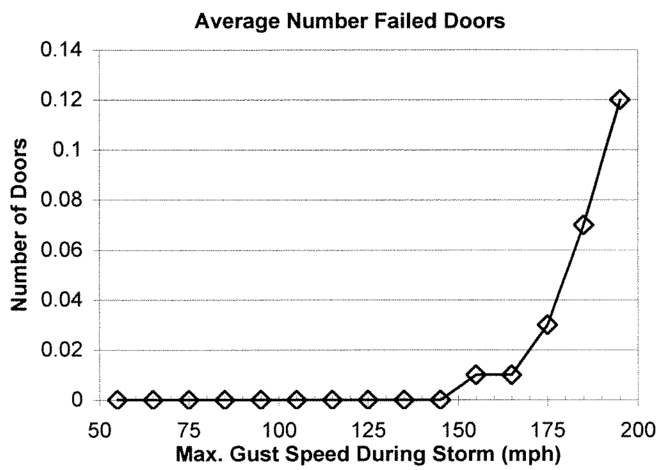

Average Percent of Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)

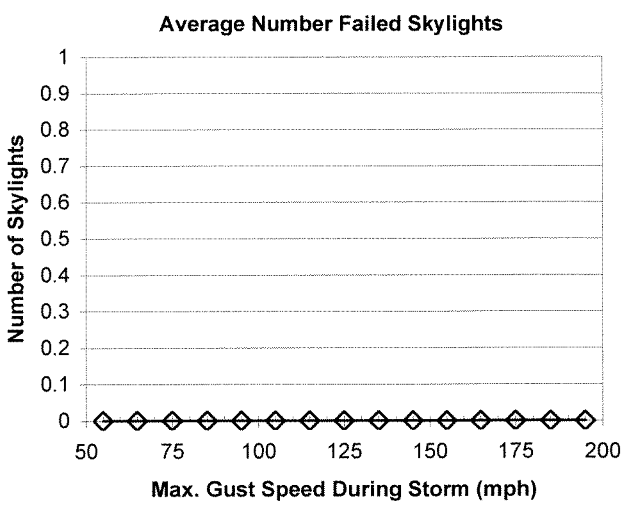
Case ID: 0013G
Dir: G:\DcaDoi2\Runs\0013GRC1RW2DK2PR100013C

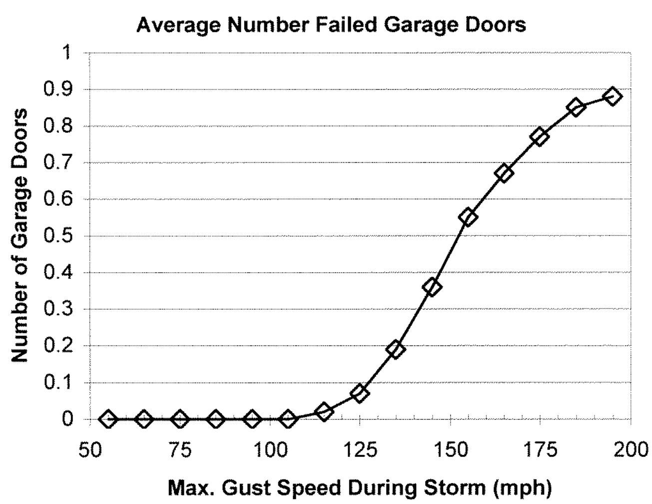


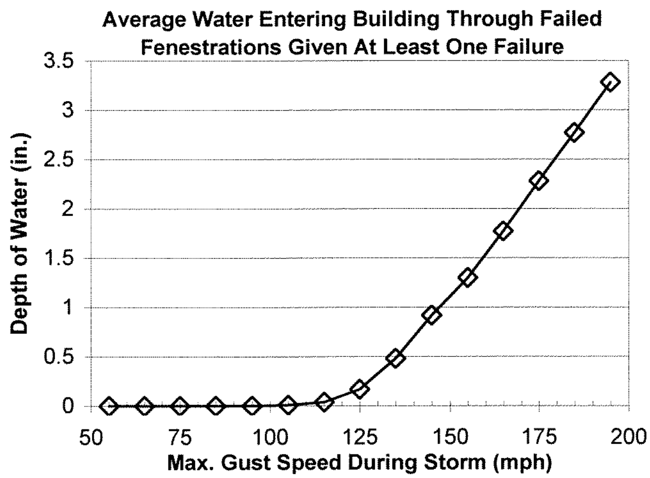


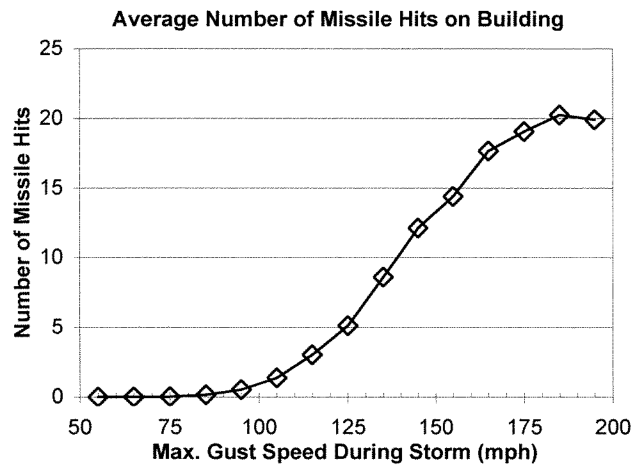


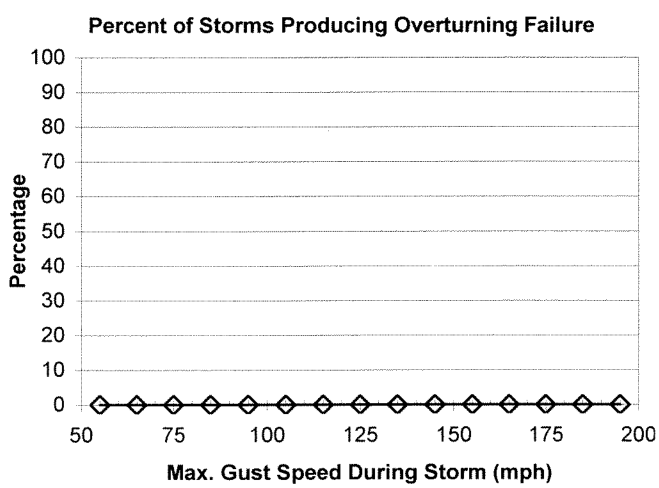


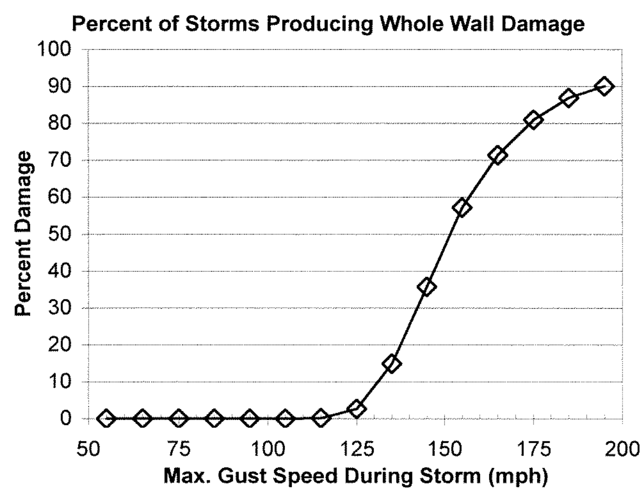


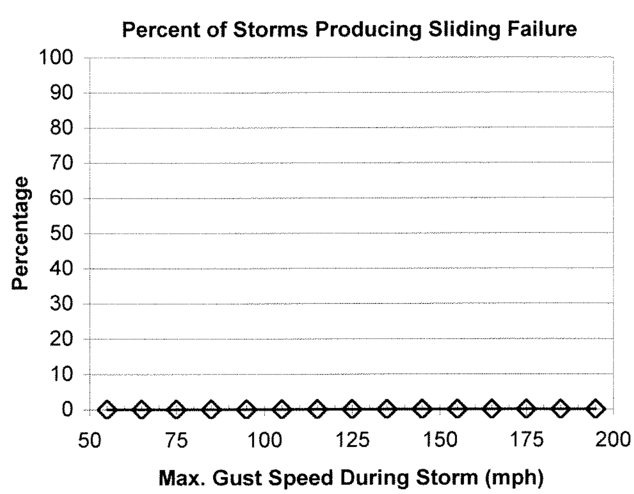



Average Water Entering Building Through Failed Fenestrations Given At Least One Failure
Depth of Water (in.)
0
0.5
1
1.5
2
2.5
3
3.5
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)


Average Number of Missile Hits on Building
Number of Missile Hits
0
5
10
15
20
25
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Overturning Failure
Percentage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Whole Wall Damage
Percent Damage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Sliding Failure
Percentage
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
Max. Gust Speed During Storm (mph)

Case ID: 0013H
Dir: H:\DcaDoi2\Runs\0013HRC2RW3DK3PR300013C

HurReport - Single Family Residential

Building Description

Stories:	1
Primary Roof Shape:	Hip
Roof Cover:	Asphalt/Fiberglass Shingles
SWR:	No
Roof/Wall Connection:	One-side Wrap
Roof Deck:	Plywood
Roof Deck Attachment:	8d/06/06/04
Wall Construction:	Stick Frame

Type	*Plan*	*Roof*	*Wall*	*Fen*	*Glazing*
Area (sf)	1800	1950	1620	421	241
Percent	NA	NA	NA	26%	15%

Protection Level	*Area (sf)*	*Percent **
Hurricane Shutter	241	15%

* percent of wall area for fens and percent of roof area for skylights.

Fen:	*Windows*	*Doors*	*Sliders*	*Garage*	*Skylights*
Cnt:	10	1	2	1	0

Wind Climate

Num of Year Sim: 300,000
Sim File: \DCADOI\HurLossArchive\WindClimateData\SIMW00013.dat

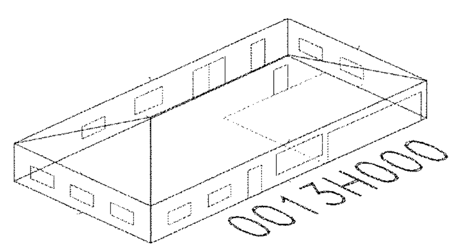
Num Sim Per Storm:	30
100 Yr Wind Speed:	142 mph
250 Yr Wind Speed:	159 mph
1000 Yr Wind Speed:	180 mph
Annual Occ. Rate:	0.57346
Latitude (deg):	25.7757
Longitude (deg):	80.2109
Orientation:	Random
Inland Distance(km):	2.5
Terrain(m):	0.03
Location:	Miami

Cat.	Number of Storms
0	143,365
I	16,302
II	7,150
III	3,794
IV	1,310
V	114
Total	172,035

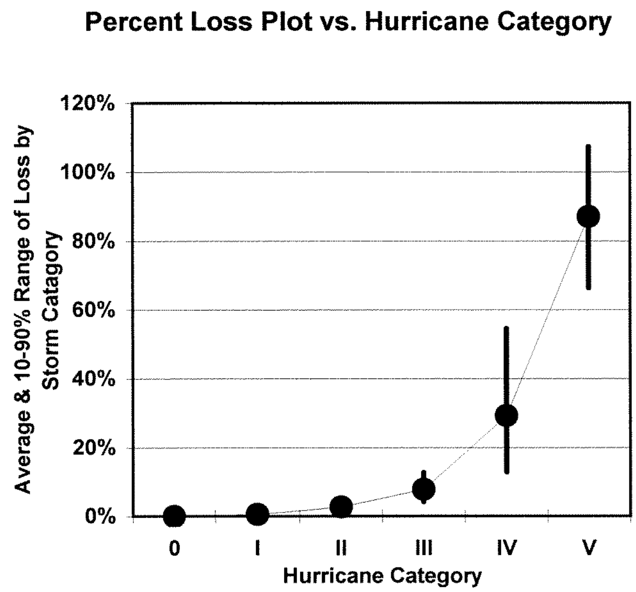
Economic Description

	Value	*Cap*
Building:	$105,000.00	1.25
Contents:	$73,500.00	1.00
ALE:	$21,000.00	1.00
Deductible:	0/2100/5250	

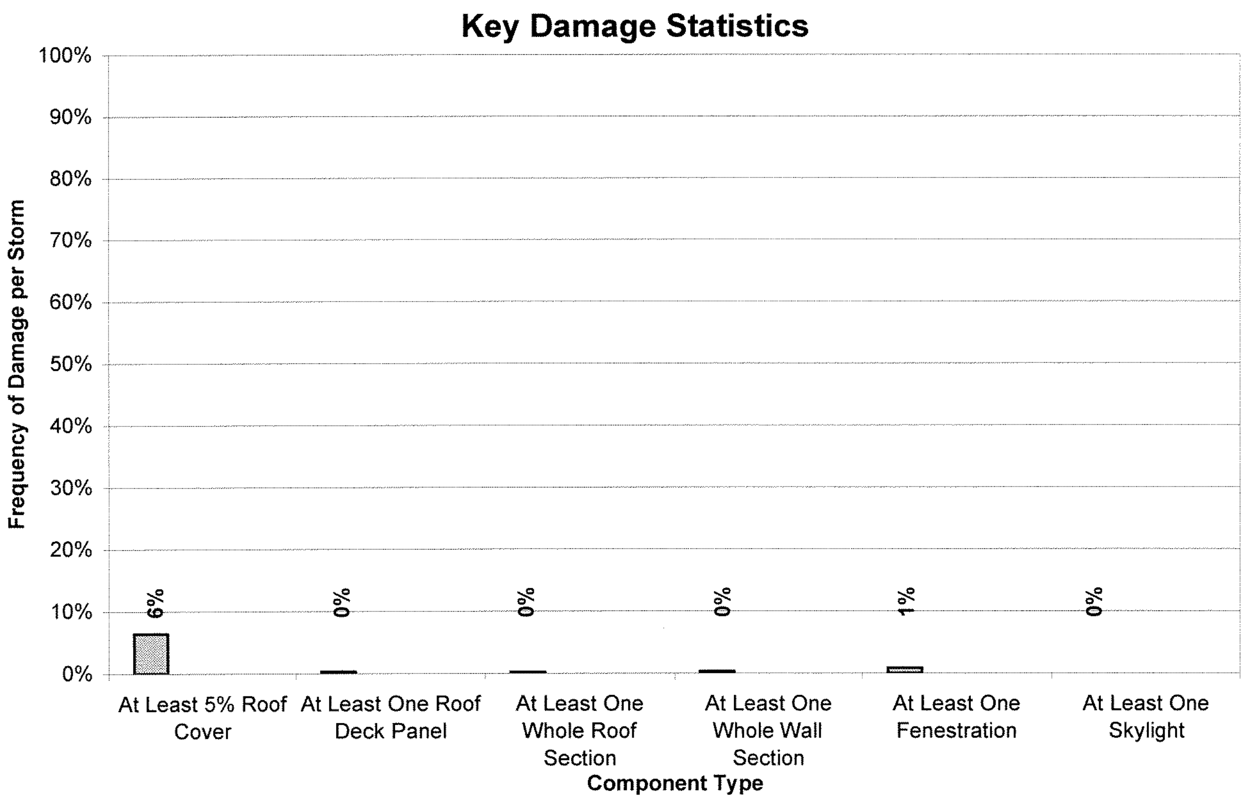
Cap Cont Cov:	0.7
Cap ALE Cov:	0.2
OHP:	1.2
R&R:	1.25

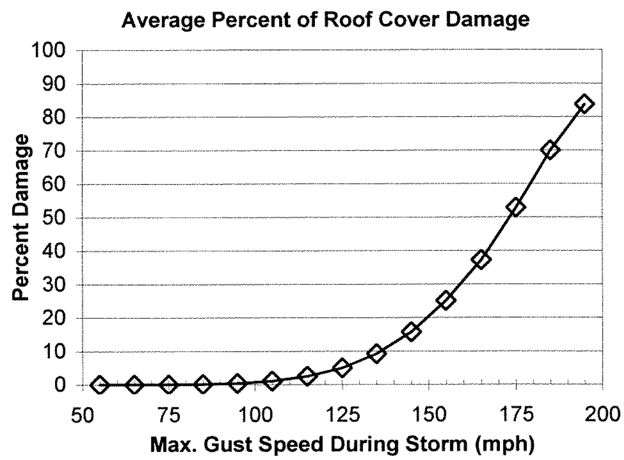


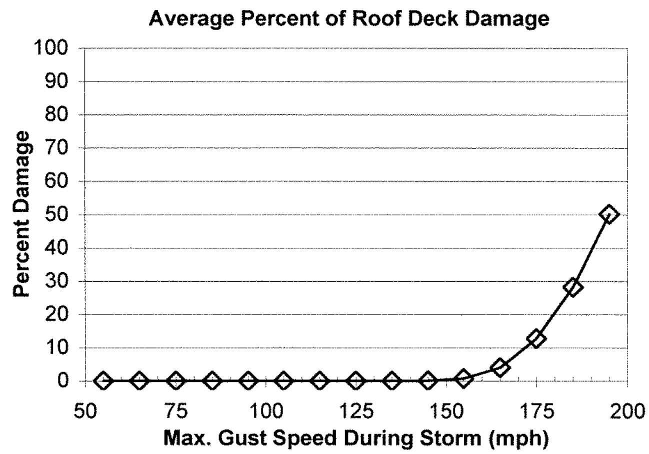
Case ID: 0013H
Dir: H:\DcaDoi2\Runs\0013HRC2RW3DK3PR300013C

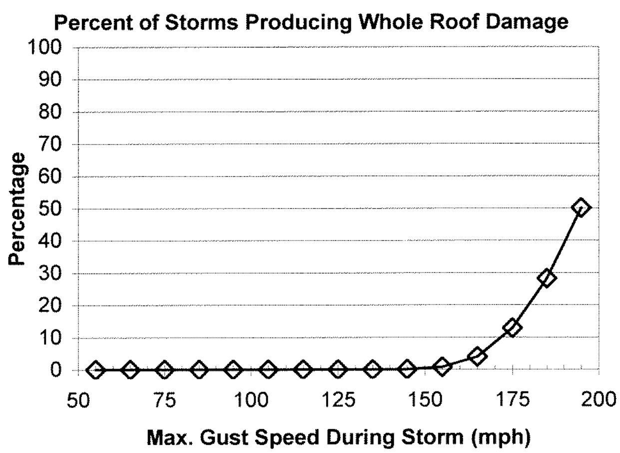


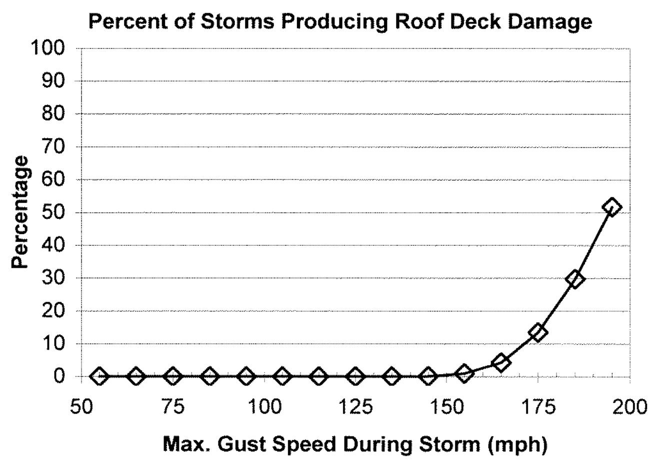
Average Physical Damage State: 0.15

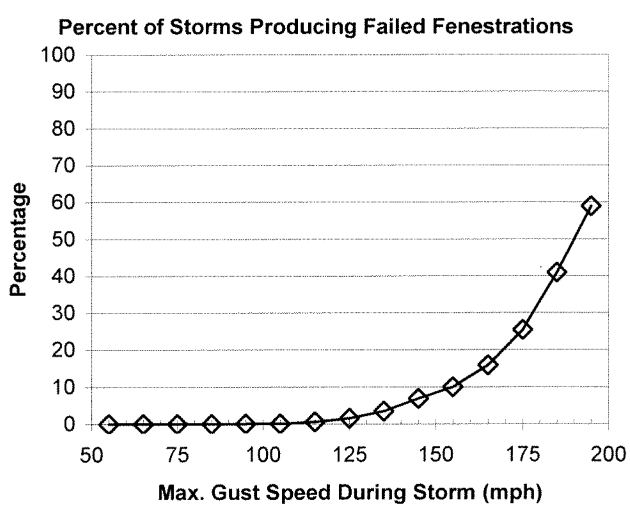


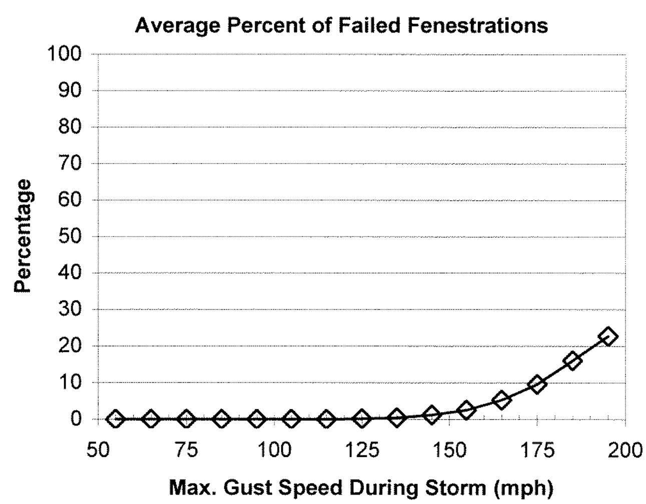

Average Percent of Roof Cover Damage
Percent Damage
Max. Gust Speed During Storm (mph)

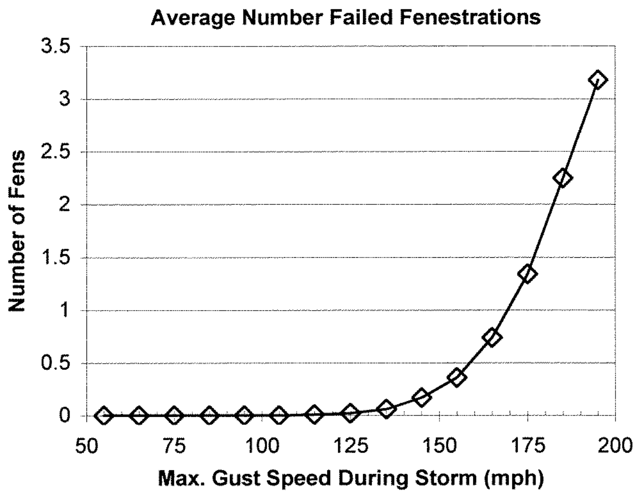

Average Percent of Roof Deck Damage
Percent Damage
Max. Gust Speed During Storm (mph)

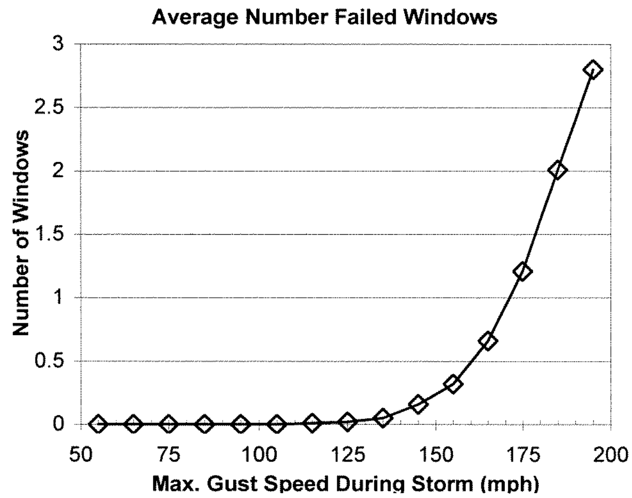

Percent of Storms Producing Whole Roof Damage
Percentage
Max. Gust Speed During Storm (mph)

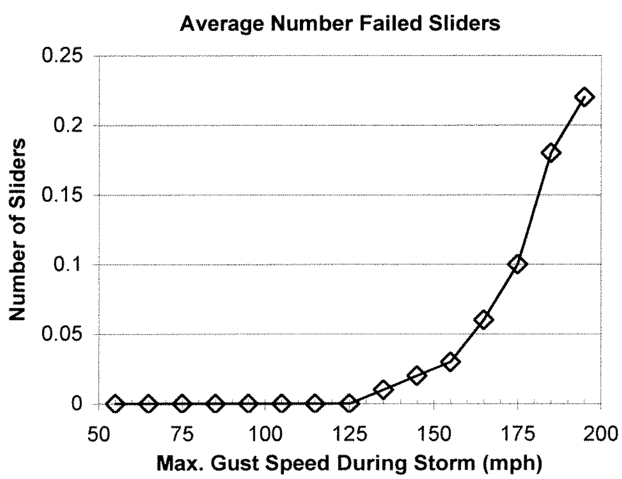

Percent of Storms Producing Roof Deck Damage
Percentage
Max. Gust Speed During Storm (mph)

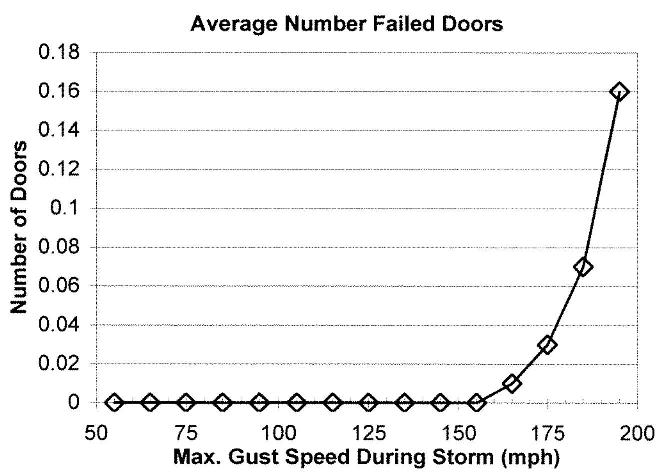

Percent of Storms Producing Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)

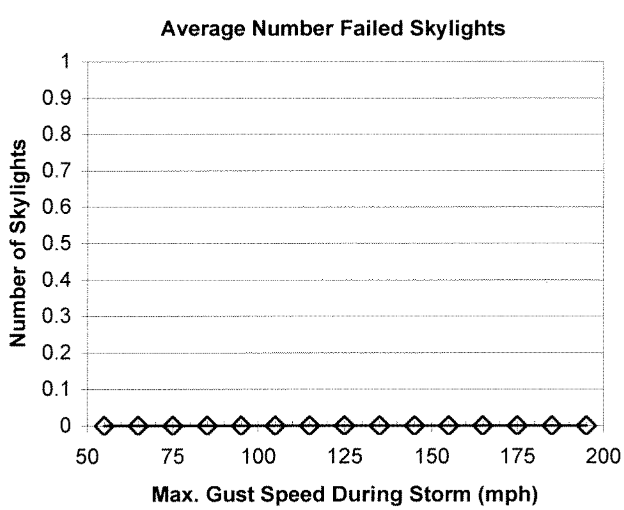

Average Percent of Failed Fenestrations
Percentage
Max. Gust Speed During Storm (mph)

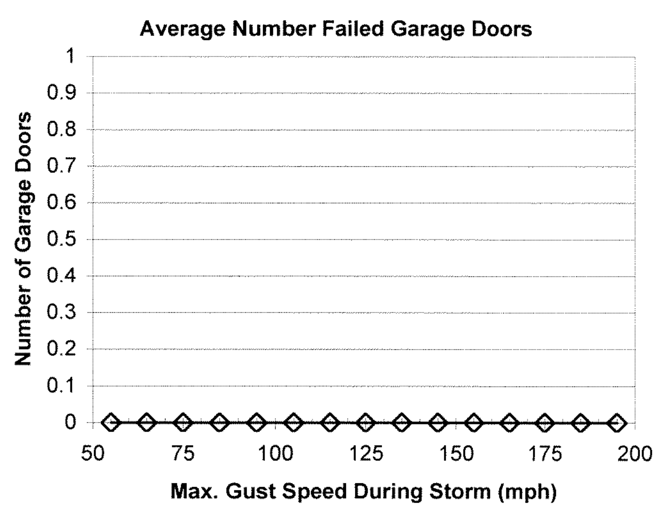

Average Number Failed Fenestrations
Number of Fens
Max. Gust Speed During Storm (mph)

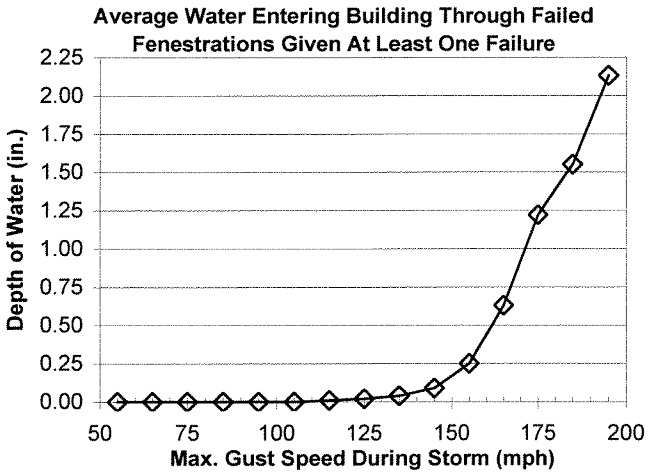

Average Number Failed Windows
Number of Windows
Max. Gust Speed During Storm (mph)

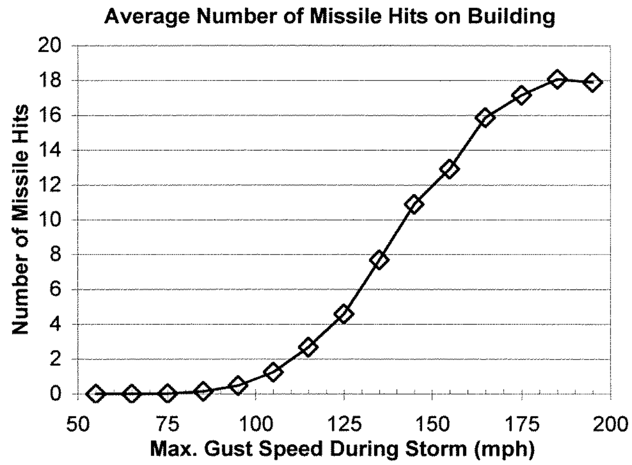

Average Number Failed Sliders
Number of Sliders
Max. Gust Speed During Storm (mph)

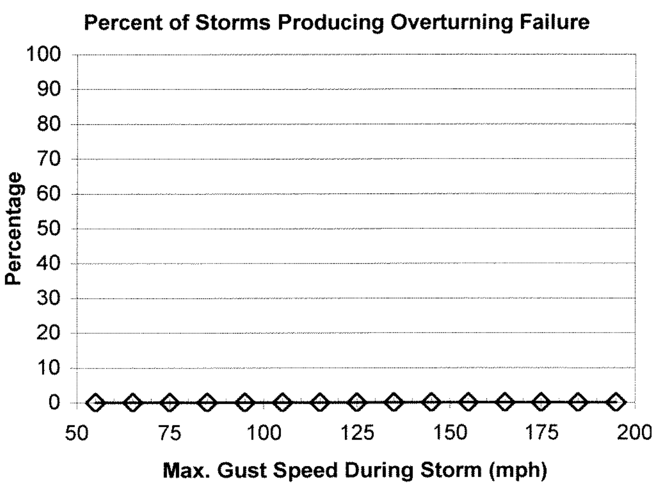

Average Number Failed Doors
Number of Doors
Max. Gust Speed During Storm (mph)

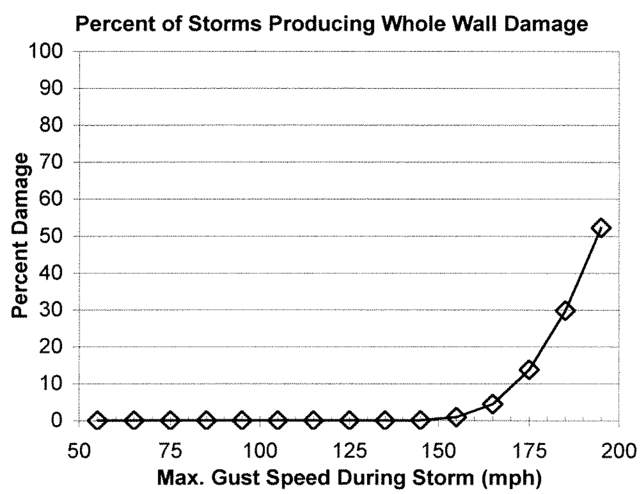

Average Number Failed Skylights
Number of Skylights
Max. Gust Speed During Storm (mph)

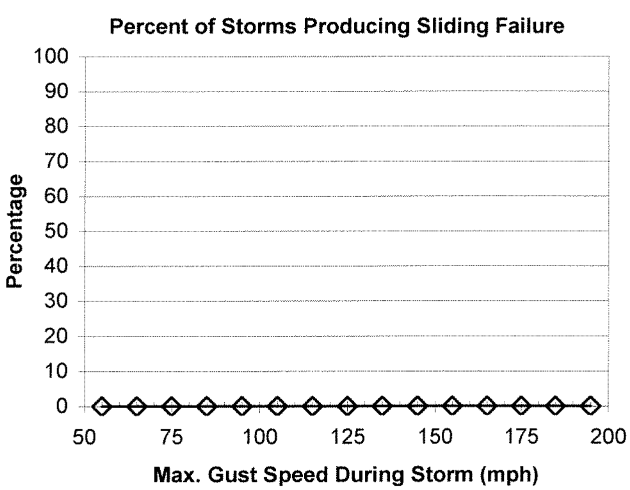

Average Number Failed Garage Doors
Number of Garage Doors
Max. Gust Speed During Storm (mph)


Average Water Entering Building Through Failed Fenestrations Given At Least One Failure
Depth of Water (in.)
Max. Gust Speed During Storm (mph)


Average Number of Missile Hits on Building
Number of Missile Hits
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Overturning Failure
Percentage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Whole Wall Damage
Percent Damage
Max. Gust Speed During Storm (mph)


Percent of Storms Producing Sliding Failure
Percentage
Max. Gust Speed During Storm (mph)

APPENDIX E:

WIND RESISTIVE DESIGN FEATURES AND LOSS ANALYSIS FOR NEW CONSTRUCTION

APPENDIX E: WIND RESISTIVE DESIGN FEATURES AND LOSS ANALYSIS FOR NEW CONSTRUCTION

E.1 General

This appendix describes the design work that has been completed on the sample homes in this study under the Florida Building Code, as they relate to the wind resistance of the building. It also presents the basic relativity results from our damage/loss simulations and the methods that have been used to simplify the final tables to those that appear in Table 4-1.

E.2 Design Options

There are four definitions/ interpretations in the FBC that warrant some discussion with respect to wind loads. The first is the definition of "openings" and how that affects the assumption of enclosed vs. partially-enclosed designs; the second is the FBC definition of exposure categories, the third is load combinations; and the fourth is the truss design load. For each of the houses, two design scenarios have been considered – one for enclosed and one for partially-enclosed buildings under the FBC.

E.2.1 Partially Enclosed vs. Enclosed Design

In designing a building, an engineer must consider the effect of whether the wind is able to enter the building and change the loading pattern on the building components. Building codes define three conditions. The first is an "Enclosed" building where the envelope is completely closed, and only wind "leaking" around doors, windows, framing, etc. is allowed to affect the interior of the building. The second condition is called an "Open" building such as a stadium grand stand where wind can freely enter the inside of the structure.

In between these two conditions is the third case, which is a "Partially Enclosed" building, where openings are assumed to exist in one or more faces of the building. These openings allow the wind to create pressures inside the building. These "internal" pressures for partially enclosed designs are typically larger than the internal pressures in an enclosed building. Hence, partially enclosed designs that are based on larger internal pressures typically result in individual parts of the structure being stronger than if designed to an "enclosed" condition. However, the openings (windows, doors, etc.) in partially enclosed designs are vulnerable to wind-borne debris impact failures and the resulting wind and rain water damage to the building interior and contents. Determining which condition is appropriate for a given building depends on the number and size of the openings in a building.

For insurance rating purposes, clearly the design option chosen for a house in the Wind-Borne Debris Region of the FBC (see Section 2.2) is a key factor in hurricane loss mitigation. Enclosed designs in the Wind-Borne Debris Region will have all glazed openings protected[1] for debris impact. These buildings will perform better than partially-enclosed designs and will have lower losses.

E.2.2 The Definition of "Openings"

In the SBC97, an opening was defined as*: "windows doors and skylights that are not* designed *as components and cladding"*. The implication of this definition is that if a designer specified the wind load that the window must meet, then the window is not considered to be an opening. Based on this

[1] In the HVHZ, all openings must be protected (see Section 1626 of FBC 2001).

definition, the building does not have to be designed as a partially enclosed structure when the house has no opening protection.

In contrast, ASCE 7-98 and the FBC have adopted a different definition of opening as: *"in wind borne debris regions, exterior glazing shall be assumed open unless impact resistant or shuttered."* This change in opening definition means that for those buildings in the wind borne debris region – the structure must have some form of impact protection for all glazed openings, or alternatively be designed as a partially-enclosed structure (to withstand higher wind pressures that occur when an "opening" occurs in the exterior of the building). Designing for the partially-enclosed condition means that all design pressures are increased as a result of potentially higher internal pressure loads that the structure may experience. This includes loads on the roof deck, roof trusses, windows and doors, as well as all other parts of the structure.

In the FBC opening definition, strictly speaking, doors without glazing escape the impact rating requirements because the definition of openings is phrased in terms of "glazed" openings. The FBC definition of glazed openings is assumed to mean any door or window containing glass. Thus, garage doors and entrance doors without windows only have to meet wind pressure requirements in the wind borne debris region; they do not have to meet any of the referenced impact standards. The current rules for opening protection credits used by many insurance companies, such as FWUA, require all windows *and* doors to be protected. Thus, houses designed strictly to the FBC enclosed scenario will require a new class that corresponds to protection of only glazed openings.

E.2.3 The Definition of Terrain Exposure[2]

The FBC has adopted a different definition of Exposure C than appears in the text of ASCE 7-98. Exposure C, (known as the open country exposure) in the FBC is defined as Broward and Miami-Dade counties (HVHZ), barrier islands, and 1500 ft from the coastline in the rest of the state. All other buildings will be designed for Exposure B regardless of whether the structure is in the middle of a field or in the middle of a suburb. Hence, the loss relativities for new construction are computed separately for terrain Exposures B and C since the design loads are dependent on terrain.

E.2.4 Load Combinations

There has been a change in the design load combinations for the Allowable Stress Design method specified in ASCE 7-98 and thus in FBC. Previously, a designer calculates the wind loads on the assembly and calculates the forces considering both the full dead load of the assembly, and the wind loads. In ASCE 7-98, the designer is now required to consider a design scenario where the full wind loads and only 60% of the dead load act upon the assembly. The net result of this change is that connection sizes may be significantly larger than those calculated strictly by earlier codes, such as the SBC 97 provisions.

E.2.5 Effect of Loading Assumptions in Truss Strap Design

When designing the roof straps, a designer is presented two methods of calculating the loads on the roof straps under the SBC and the FBC. One set of loads in the code is called Components and Cladding (C&C) loads and these are to be applied to any cladding or member that receives wind loads

[2] ASCE-7 and wind engineers use the term "Exposure" to define the earth's surface roughness for purposes of grouping this roughness into several distant categories for wind load estimation. Insurers need to be aware of this use of the term "Exposure" when reading building code and wind engineering literature.

directly from the wind. These loading pressures take into account the lack of correlation of the wind gusts over larger and larger areas. The other set of loads in the code are called Main Wind Force Resisting System (MWFRS) loads and are intended to calculate the effect of loads acting on several surfaces at once. Much discussion and debate among design professionals over which loading set is appropriate for roof trusses has ensued over the years.

The ASCE 7-98 document says that trusses are to be considered as both C&C loading and MWFRS loading (see page 243 of ASCE 7-98 commentary). The commentary describes the situation where long span trusses should be designed for MWFRS loads and individual members of the truss designed for C&C loads. Unfortunately, the commentary does not discuss what is appropriate for the straps holding the truss to the wall, nor does it define what constitutes a long span truss. Section 6.5.12.1.3 of the ASCE 7-98 does indicate a threshold of 700 square feet of tributary area for considering a component to be designed with MWFRS loads. From this threshold, a logical argument could be made that most residential trusses are not large enough to qualify for the MWFRS loads, and therefore should be designed for C&C loads, and subsequently, the strap size chosen to be consistent with C&C loads. For residential structures, both the MWFRS and the C&C loads should be checked, and the larger of the two chosen. Typically, for residential construction, the C&C loads are significantly higher than the MWFRS loads.

The language in Section 1606 of the SBC is quite vague on which loading set is appropriate for strap uplift calculations. It does refer to ASCE 7-95, which contains the same information as discussed in ASCE 7-98 above. Based on these comments the same conclusion should be made about residential trusses - in other words the strap size should be designed for C&C loads as well.

However, the prescriptive codes referenced by the FBC are founded on the SBC97 (or SBC95) building code, and clearly state in each document that the truss strap design has been completed with MWFRS loads. Conversations with designers and truss manufacturers indicate that much of the industry is conforming to the MWFRS loads. Therefore, we have evaluated the design options both ways. The design calculations in Appendix F, and summarized in Tables E-1 through E-3, present both the C&C loading approach and the MWFRS loading approach.

While the C&C loads would govern the technically correct design method, the relativity results indicate that the effect on loss costs is minor. Therefore, the relativity results presented here will only show the MWFRS results.

E.2.6 Model Parameters

ARA has performed design calculations for wind loads on various components of a wood frame and masonry version of each of the three houses in this study. The following key components that affect the wind resistance of the building will vary depending on which wind speed the building is designed for:

- Roof Deck Nailing Pattern
- Window and Door Design Pressure
- Roof Wall Tie Down

In addition these other items have also been examined:

- FBC Equivalent Roof Cover
- Opening Protection
- Wood Frame Wall Lumber Size
- Masonry Wall Vertical Reinforcement Spacing
- Foundation

The design calculations for one of the houses at 130 mph design wind speed are shown in Appendix F. These calculations were repeated for the wind speed/exposure combinations at each of the 31 points in this study (see Table 2-2). Tables E-1, E-2, and E-3 shows the results of these design calculations for each of the three study homes.

The design calculations indicate that a minimum nail size of 8d should be used throughout the state. The nailing pattern for the roof varies from the standard 6″/12″ pattern in the lower wind speed zones in the state, to the 6″/6″ spacing in the high wind zone areas. In all of these designs, the nailing pattern at the edge of the roof is assumed to drop to a 4″ spacing next to the gable end (if appropriate). The nailing pattern has been determined based on Zone 2/3 pressures and is applied uniformly across the entire roof.

The hurricane strap size has been calculated for a truss using MWFRS loads. Both end trusses and interior trusses were calculated for each building. Tables E-1 through E-3 present the reaction of an interior truss that is typical for 75% of the roof-wall connections in a given building.[3] Because the FBC now uses a load combination of 60% of the dead load of the roof to resist uplift, the design values of the straps are larger than they were for the SBC97.

Each of the buildings in the HURLOSS simulations were considered to be wood frame structures with FBC Equivalent shingle roof covers and no Secondary Water Resistance.

E.2.7 Effect on Wall Construction

ARA also designed a wood frame wall and a masonry wall for each of the three buildings in this study. The wood frame wall was examined for capacity in bending due to wind loads, axial loads from the roof and shear loads along the length of the wall. Table E-4 presents the results of this analysis for the large house and shows that there is very little variance in the construction techniques used in the wall construction. However, the design calculations indicate that a standard 2x4 wall at 16 inch spacing is adequate if an appropriate grade of wood is used to carry the wind loads in almost all parts of the state.

For the masonry house, ARA checked the spacing of the vertical reinforcement and found that the required spacing varied as shown in Table E-4.

ARA analyzed the new construction homes with wood frame walls and masonry walls and found that the wall construction hardly affects the relativity, as discussed in Section 3.3. Although our models show that the failure rates of wood frame are higher than those of masonry, the model also indicates that the wall failures are correlated with the whole roof failures, which already make the whole structure a write-off, and thus the effect of the walls is minimal.

E.2.8 Effect on Foundation Design

Calculations of the anchor bolts required to resist the wind loads according to the FBC were completed (see Appendix F). As demonstrated by the foundation failure discussion in Section 3.3.6, the failure of the foundation affects the relativities when the foundation relies only on the weight of the structure to resist the wind shear and uplift forces. Any type of rebar or anchor bolts will essentially eliminate the foundation failure's effect on the relativities. Since all foundations built according to the FBC will be restrained in some fashion, the foundation type has not been included as a variable in the new construction matrix.

E.3 Analysis of Loss Cost Relativities

For each of the 31 locations, the roof deck nailing pattern, the roof-wall connection, and the window design pressures on the three study homes were designed to the minimum

[3] Assuming uniform spacing of similar size trusses throughout roof plan.

Table E-1. Design values for Florida Building Code for House 0011 (Gable or Hip Roof)

Wind Speed	Exposure	Enclosed: Design Strap C&C (lbf)	Enclosed: Design Strap MWFRS (lbf)	Enclosed: Roof Nail Spacing[2]	Enclosed: Window Design Pressure (psf)	Partially Enclosed[1]: Design Strap C&C (lbf)	Partially Enclosed[1]: Design Strap MWFRS (lbf)	Partially Enclosed[1]: Roof Nail Spacing[2]	Partially Enclosed[1]: Window Design Pressure (psf)
100	B	377	267	6"/12.0"	-24				
110	B	486	352	6"/12.0"	-28				
120	B	605	446	6"/12.0"	-33	799	657	6"/9.6"	-41
	C	762	570	6"/9.6"	-40	998	826	6"/8.0"	-50
130	B	734	548	6"/9.6"	-39	962	795	6"/8.0"	-48
	C	919	693	6"/8.0"	-47	1196	993	6"/6.9"	-59
140	B	874	657	6"/8.0"	-45	1139	945	6"/6.9"	-56
	C	1008	826	6"/6.9"	-54	1409	1175	6"/6.0"	-68
146	C	1196	911	6"/6.9"	-59				
150	B	1024	775	6"/6.9"	-52	1328	1105	6"/6.0"	-64
	C	1270	969	6"/6.0"	-63	1639	1369	6"/5.3"	-78

1 Partially-enclosed designs are not applicable to wind speeds less than 120 mph..
2 Roof nail spacing of 8d nail in 15/32" plywood deck uniformly across deck, except use a 4" spacing for 4ft on gable edge if applicable.

Table E-2. Design values for Florida Building Code for House 0013 (Gable or Hip Roof)

Wind Speed	Exposure	Enclosed: Design Strap C&C (lbf)	Enclosed: Design Strap MWFRS (lbf)	Enclosed: Roof Nail Spacing[2]	Enclosed: Window Design Pressure (psf)	Partially Enclosed[1]: Design Strap C&C (lbf)	Partially Enclosed[1]: Design Strap MWFRS (lbf)	Partially Enclosed[1]: Roof Nail Spacing[2]	Partially Enclosed[1]: Window Design Pressure (psf)
100	B	442	319	6"/12.0"	-24				
110	B	571	422	6"/12.0"	-28				
120	B	712	535	6"/12.0"	-33	955	795	6"/9.6"	-41
	C	899	685	6"/9.6"	-40	1194	1000	6"/8.0"	-50
130	B	865	658	6"/9.6"	-39	1151	863	6"/8.0"	-48
	C	1085	834	6"/8.0"	-47	1431	1204	6"/6.9"	-59
140	B	1031	791	6"/8.0"	-45	1363	1145	6"/6.9"	-56
	C	1286	995	6"/6.9"	-54	1688	1424	6"/6.0"	-68
146	C	1414	1094	6"/6.9"	-59				
150	B	1209	934	6"/6.9"	-52	1590	1340	6"/6.0"	-64
	C	1502	1168	6"/6.0"	-63	1963	1660	6"/5.3"	-78

1 Partially-enclosed designs are not applicable to wind speeds less than 120 mph..
2 Roof nail spacing of 8d nail in 15/32" plywood deck uniformly across deck, except use a 4" spacing for 4ft on gable edge if applicable.

requirements of the Florida Building Code as described above. The homes were also modeled with roof cover, wood walls, and foundation characteristics consistent with the FBC 2001. These "designed" homes were analyzed with HURLOSS to estimate the loss cost of each of the homes at each location.

The average of the loss costs for the base class (typical) houses in the existing building study were calculated for each location, and used to determine the relativity of each "designed" home. That is, we normalized the new construction relativities by the same values in the existing building study so that the relativity tables would be consistent with each other. Table E-5 shows how the relativity results for 2% deductible vary from one location in the state to another.

Table E-3. Design Values for Florida Building Code for House 0002 (Gable or Hip Roof)

Wind Speed	Exposure	Enclosed				Partially Enclosed			
		Design Strap C&C (lbf)	Design Strap MWFRS (lbf)	Roof Nail Spacing	Window Design Pressure (psf)	Design Strap C&C (lbf)	Design Strap MWFRS (lbf)	Roof Nail Spacing	Window Design Pressure (psf)
100	B	728	527	6"x12.0"	-24				
110	B	941	698	6"x12.0"	-29				
120	B	1175	885	6"x12.0"	-35	1580	1315	6"x9.6"	-43
	C	1508	1152	6"x9.6"	-43	2006	1681	6"x8.0"	-53
130	B	1428	1088	6"x9.6"	-41	1904	1593	6"x8.0"	-50
	C	1819	1402	6"x8.0"	-50	2404	2022	6"x6.9"	-62
140	B	1448	1307	6"x8.0"	-47	2254	1893	6"x6.9"	-58
	C	2156	1671	6"x6.9"	-58	2834	2391	6"x6.0"	-72
146	C	2370	1843	6"x6.0"	-63				
150	B	1996	1543	6"x6.9"	-54	2630	2216	6"x6.0"	-67
	C	2517	1961	6"x6.0"	-67	3296	2787	6"x5.3"	-82

[1] Partially-enclosed designs are not applicable to wind speeds less than 120 mph..
[2] Roof nail spacing of 8d nail in 15/32" plywood deck uniformly across deck, except use a 4" spacing for 4ft on gable edge if applicable.

Table E-4. House 0002 Wall Design Parameters

Exposure	Wind Speed	Enclosed		Partially Enclosed	
		Wood Wall Framing Size and Spacing*	Masonry Wall Vertical Reinforcement Spacing (ft)	Wood Wall Framing Size and Spacing*	Masonry Wall Vertical Reinforcement Spacing (ft)
B	100	2x4 @ 16"	10' 8"		
	110	2x4 @ 16"	9' 4"		
	120	2x4 @ 16"	8' 8"	2x4 @ 16"	8' 0"
	130	2x4 @ 16"	8' 0"	2x4 @ 16"	7' 4"
	140	2x4 @ 16"	7' 4"	2x4 @ 16"	6' 8"
	150	2x4 @ 16"	6' 8"	2x4 @ 16" **	6' 0"
C	120	2x4 @ 16"	8' 0"	2x4 @ 16"	6' 8"
	130	2x4 @ 16"	7' 4"	2x4 @ 16"	6' 8"
	140	2x4 @ 16"	6' 8"	2x4 @ 16" **	6' 0"
	146	2x4 @ 16"	6' 8"		
	150	2x4 @ 16" **	6' 0"	2x4 @ 12"	5' 4"

* Wood species of wood wall: Southern Pine No. 2 Standard, 8ft wall height - based on Zone 4 pressures.
** These designs will require stud spacing of 12 inches at corners (Zone 5).

These results present relevant design options for each of the locations. For example, no partially enclosed condition is shown for points in the High Velocity Hurricane Zone because all buildings in this zone must be designed as enclosed structures with opening protection.

E.3.1 Simplifying the Loss Relativity Tables

In order to make these results useful, we have considered ways to reduce the relativity table for new construction to a smaller, easier to use table. The first is the reduction of the

Table E-5. Average of Relativity for Minimal Designed Homes at All Simulated Points (2% Deductible)

Relativity – 2% Deductible			Non-WBDR (Enclosed)[1]		WBDR (Enclosed)[2]		WBDR (Part. Enclosed)[3]	
			No Opening Protection		Opening Protection		No Opening Protection	
Exposure	Wind Speed	ID	Other Roof	Hip Roof	Other Roof	Hip Roof	Other Roof	Hip Roof
B	100	1	0.762	0.506				
		2	0.762	0.509				
	110	3	0.668	0.518				
		4	0.663	0.517				
		5	0.658	0.514				
		6	0.656	0.500				
	120	7	0.606	0.505				
		8			0.492	0.415	0.630	0.530
		9			0.503	0.420	0.608	0.510
		10			0.484	0.411	0.586	0.495
		11			0.513	0.423	0.617	0.512
	130	15			0.488	0.418	0.637	0.538
		16			0.477	0.409	0.593	0.504
		17			0.468	0.404	0.602	0.513
	140	21			0.465	0.404	0.626	0.532
	150	25			0.464	0.406	0.642	0.548
C	120	12			0.278	0.226	0.362	0.291
		13			0.281	0.224	0.348	0.276
		14			0.273	0.224	0.366	0.297
	130	18			0.263	0.220	0.362	0.299
		19			0.266	0.222	0.366	0.302
		20			0.266	0.223	0.372	0.308
	140	22			0.270	0.229	0.399	0.332
		23			0.264	0.223	0.378	0.313
	150	26			0.270	0.233	0.412	0.346
		27			0.291	0.249	0.456	0.384
HVHZ	140	28			0.273	0.233		
		29			0.249	0.216		
	146	30			0.277	0.239		
		31			0.257	0.223		

[1] Relativities for non-Wind Borne Debris Regions
[2] Relativities for Wind Borne Debris Regions with opening protection (shutters or impact resistant glazing)
[3] Relativities for Wind Borne Debris Regions where design based on partially enclosed assumption with no opening protection.

number of wind speed zones, and the second is the combination of the Enclosed/Partially Enclosed design options with the opening protection variable. This leaves the following key variables to consider: the terrain exposure, the wind speed zones, the roof shape, and the opening protection. The following paragraphs examine the data from Table E-5 to determine which variables must be retained in the simplified version of the new construction tables and which can be averaged into the final results.

Terrain Exposure and Wind Speed Zone. There is a significant difference in relativity for buildings in Terrain Exposure C verses Terrain Exposure B. Therefore, the table has been grouped by design exposure. The relativities from Table E-5 have been plotted on graphs in Figs. E-1 to show the variation of the relativities with location/wind speed. These graphs indicate that the variation along wind speed contours is quite small and therefore a simplified version of the minimally designed new construction relativity tables may be independent of actual location. One may also note that the variation between wind speed regions is really only significant at 100, 110 and ≥ 120 mph levels. Therefore the simplified tables (presented in n Section 4) are reduced to three wind speed regions.

Comparison of Partially Enclosed to Enclosed. The results in Table E-5 indicate that the partially enclosed design case is not as effective at reducing losses as the enclosed design case. Although the partially-enclosed case has stronger components, it still does not address the issue of protecting the openings on the building. Figure E-2 shows the damage curves for the Partially Enclosed and Enclosed version of the smallest hip roof house in Ft. Lauderdale (Point 28). The difference between the two simulations is in the roof-wall connection, the roof deck strength, and the opening protection as shown in Table E-6. Although the partially-enclosed case has roof straps that are 31% stronger than the enclosed case, you see from Fig. E-2 that the whole roof still fails only in the rarest of events. Note that the window damage for the partially enclosed case is dramatically higher than the enclosed case. The higher levels of fenestration damage cause more damage internally which drives up the loss costs to higher levels. Thus the relativity between enclosed and partially enclosed is really a difference between an opening protection and no opening protection.

We examined this issue further by comparing an enclosed design without opening protection to a partially enclosed design, also without opening protection, at several locations and wind speeds. These results indicated that a small credit for partially enclosed designs of 1% is appropriate. This credit has been built into the simplified version of the relativity table (Table 4-1) in Section 4.

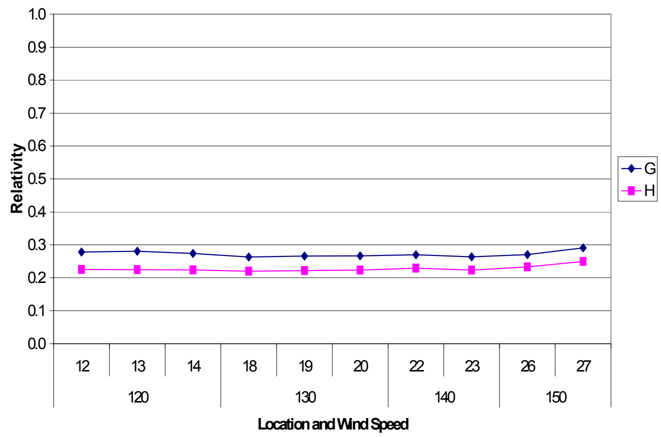
E.3.2 Comparison of New Construction Relativities to Existing Construction

The relativity of the new construction designs has been referenced to the existing construction matrix to ensure consistent application of relativities. This section compares the relativity from Section 3 with an equivalent relativity from Section 4 and explains the reason there are slight differences.

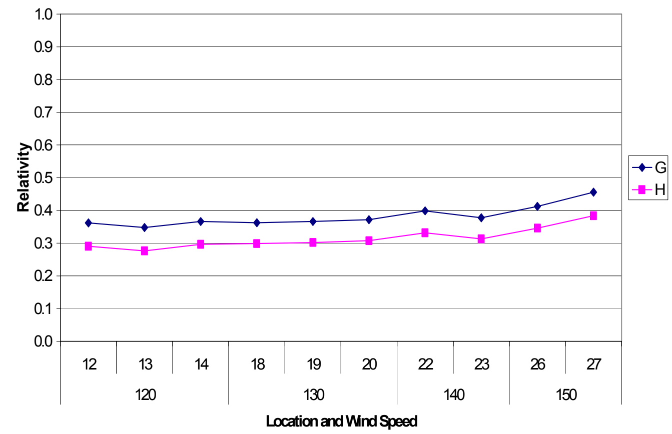
To determine where the new construction parameters map onto the existing building matrix, one must know the design capacity of the straps labeled as Clip, Single Wrap and Double Wrap in Table 3-2.

We first compare the strongest house in the existing construction table (Table 3-2, Exposure B) to the new construction loss relativity in Table E-5. For the FBC Equivalent Roof Cover, Roof-Deck Attachment C, Double Wrap Straps, Hurricane Opening Protection, and No SWR, Gable roof, the relativity is 0.49. From Table E-5, the 150 mph Exposure B Enclosed case is 0.464. The difference is due to the larger roof-wall straps in the new construction case.

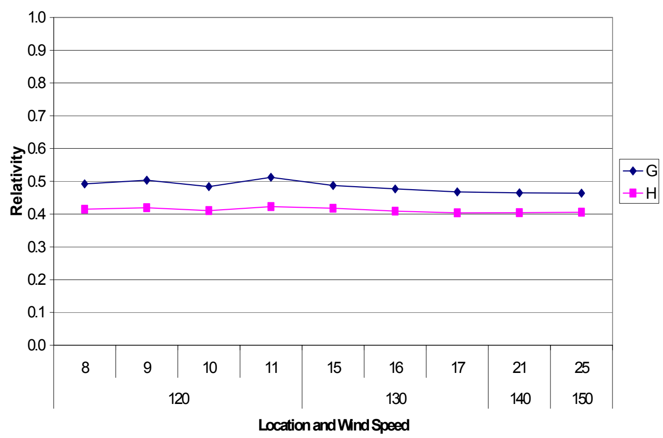
To illustrate this difference, Figs. E-3 and E-4 show a comparison between these cases for House 0013G at Miami (Point 30). The existing building simulation has a design strap size of about one-half that of the new construction design value, and a fenestration design pressure of about one-half that of the new construction version. Figure E-3 shows that the increased strap size reduces the chances of whole roof failures. It also shows there is very little difference in the failure rate of the fenestrations because the fenestrations are all protected. One can see how reducing the damage to the whole roof affects the loss curve in Fig. E-4. The increased strap size affects the loss curve the most in the Category 4 and 5 storms, reducing the average loss from 90% to 65%. Thus the further reduction in the relativity factor is a result of the increased size of the straps.



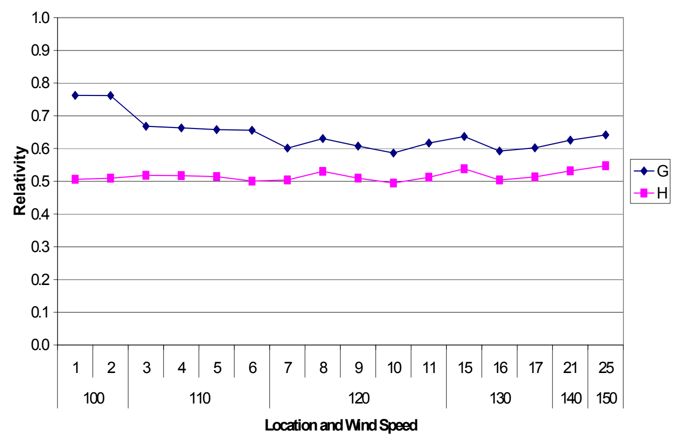
(a) Exposure C, Opening Protection



(b) Exposure C, No Opening Protection



(c) Exposure B, Opening Protection



(d) Exposure B, No Opening Protection

Figure E-1. Comparison of Loss Relativity (0% Deductible) across Location and Wind Speed for Minimum Designed New Construction Homes (G and H in legend refer to Gable and Hip homes)

There are cases, however, where the additional size of the straps is not as effective as this case presented here. If we compare the values for Terrain C results for 2% deductible, Hip roof, with no SWR, FBC Roof Cover, Roof Deck C, Double Wrap and Hurricane Opening Protection, then Table 3-3 reports a relativity of 0.25, and Table E-5 reports a relativity of about 0.24. Figure E-5 shows damage curves for whole roof failures and fenestration failures.

Notice that the damage curve for the existing case is much lower than it was for the Gable house case. Hip roof houses are stronger than gable roof houses because of the larger number of straps in the structure, as well as the reduced wind loads on a hip roof. Thus the difference between the new construction case and the existing construction case is less pronounced that it was for the gable roof example above. Figure E-6 also shows this effect in the loss curves. This figure shows that there is a smaller difference in the average loss for Category 4 storms for this hip roof building than there was for the gable roof example.

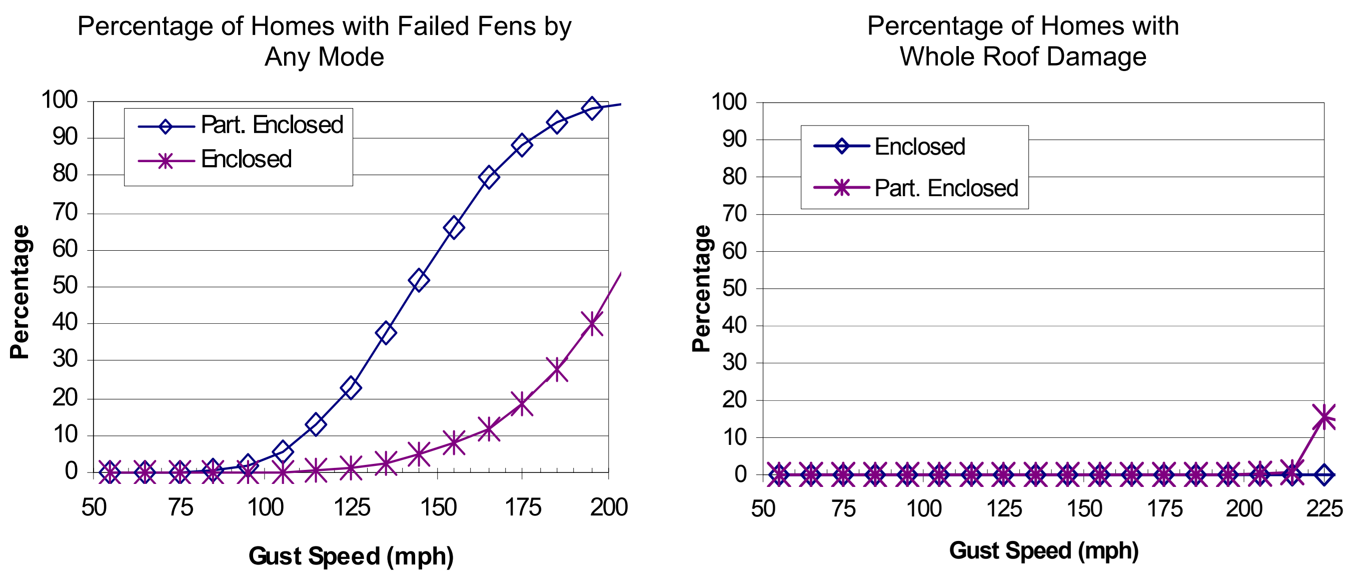


Figure E-2. Comparison of Partially Enclosed Building with Enclosed Building (0011H in Ft. Lauderdale, Exposure C)

Table E-6. Difference in Modeled Parameters Between Enclosed/Part. Enclosed for House 0011H in Ft. Lauderdale. (140 mph C Exposure)

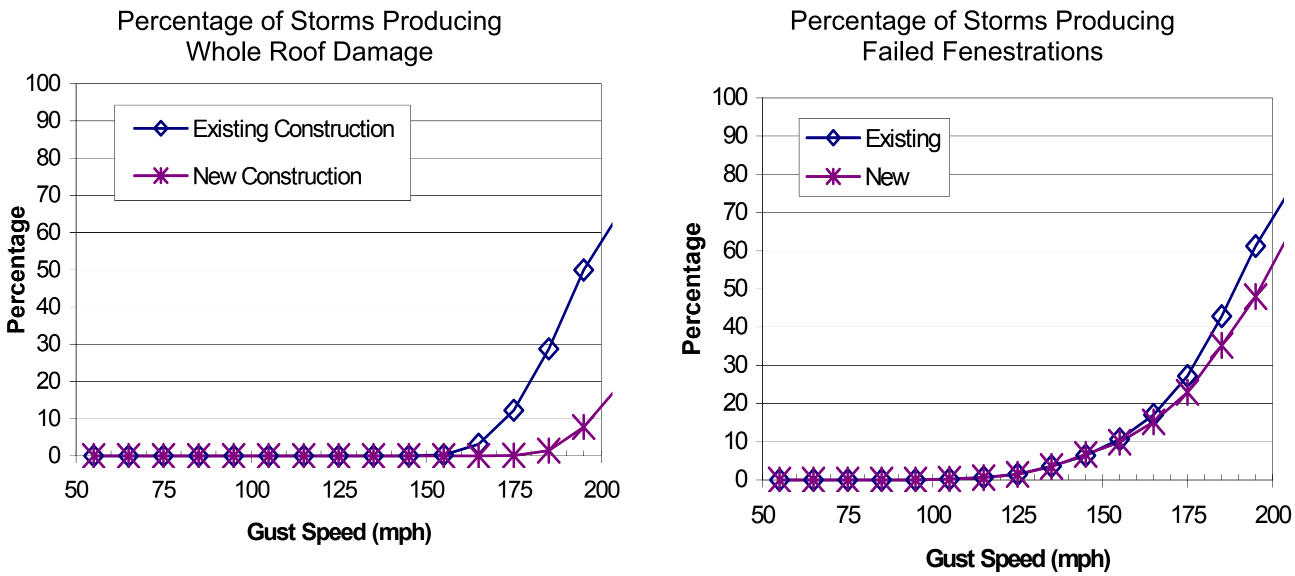
Parameter	Partially Enclosed	Enclosed
Roof-Wall Strap	1175	826
Roof Deck Nailing Pattern	8d @ 6″/6″	8d @ 6″/6.9″
Opening Protection	No	Yes

E.4 Prescriptive Standards Referenced by the FBC

The Florida Building Code allows builders to use construction details already outlined in some high wind prescriptive documents that have been prepared according to the Standard Building Code. Restrictions have been placed on these standards according to the converted gust wind speed for which they were originally derived.

The following prescriptive standards are referenced by the FBC in Chapter 16.1.1:

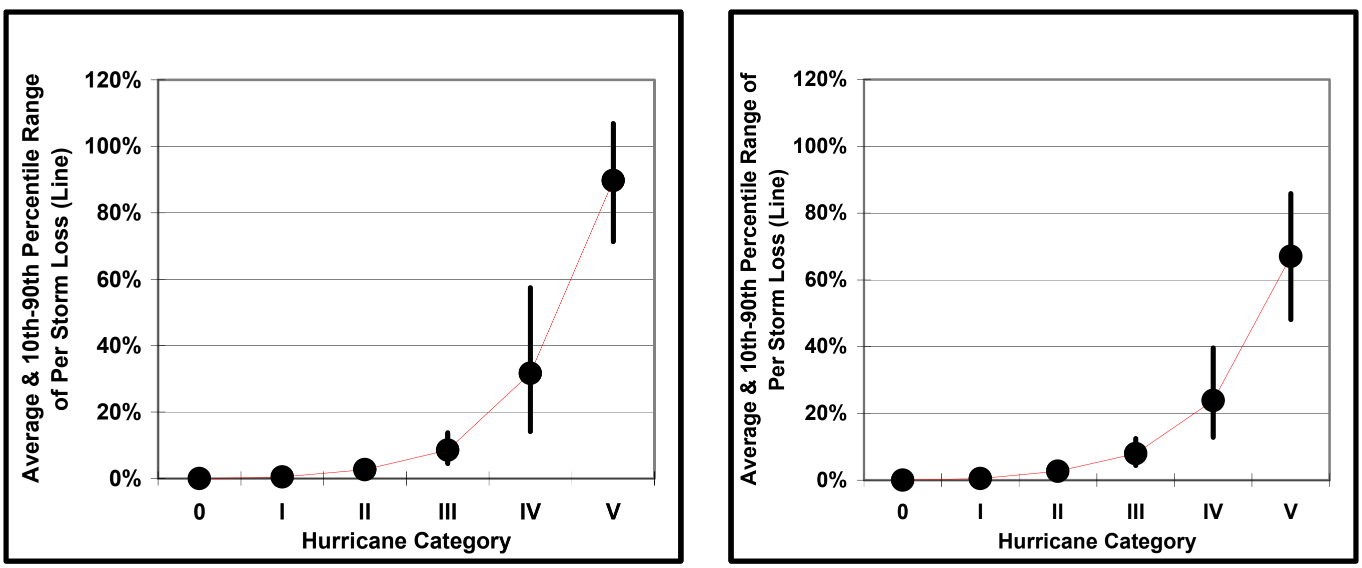
- SSTD 10-99 – Southern Standards Technical Document 10-1999. "Standard for Hurricane Resistant Residential Construction"
- WPPC – Wood Products Promotion Council – "Guide to Wood Construction in High Wind Areas"
- AF&PA – American Forest & Paper Association's – "Wood Frame Construction Manual: Guide to Wood Construction in High Wind Areas"
- FCPA – Florida Concrete & Products Association "Guide to Concrete Masonry Residential Construction in High Wind Areas".



Existing Building
Strap Strength (lbs): 557
Deck Nailing: 8d @ 6″/6″
Fen Design Pressure: 40 psf

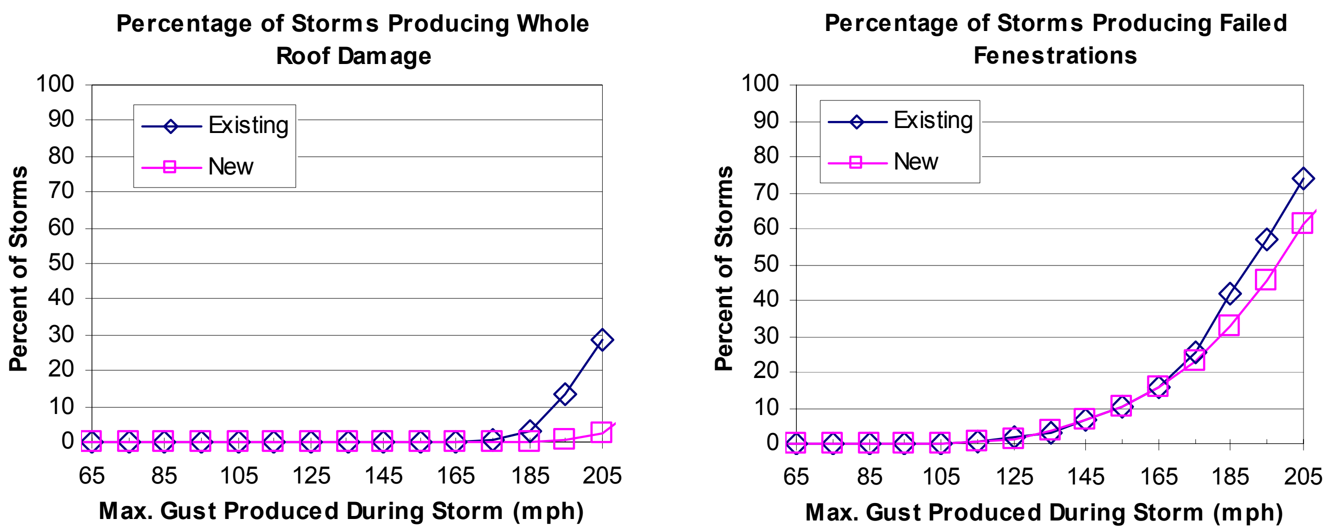
New Building:
Strap Strength (lbs): 934
Deck Nailing: 8d @ 6″/6.9″
Fen Design Pressure: ~50 psf

Figure E-3. Comparison of Existing Construction and New Construction Simulations for House 0013G at Miami in Exposure B



Existing Construction | **FBC New Construction**

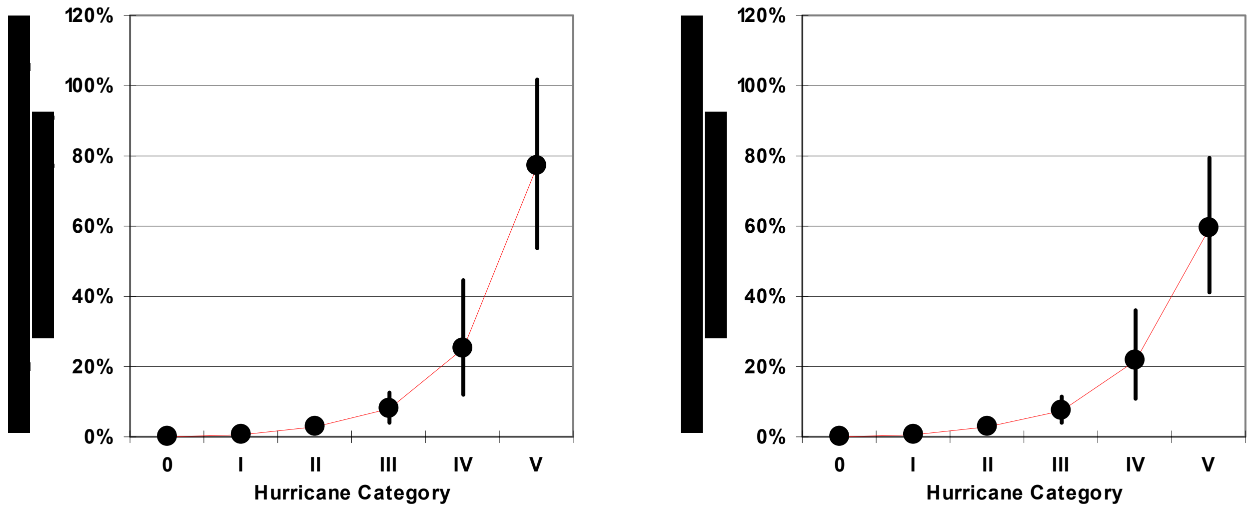
Figure E-4. Loss Curve Comparison for Existing and FBC New Construction Runs of House 0013G at Miami in Exposure B



Existing Building
Strap Strength (lbs): 557
Deck Nailing: 8d @ 6″/6″
Fen Design Pressure: 40 psf

New Building:
Strap Strength (lbs): 1168
Deck Nailing: 8d @ 6″/6.0″
Fen Design Pressure: ~60 psf

Figure E-5. Comparison of Existing Construction and New Construction Simulations for House 0013H at Miami in Exposure C



Existing Construction **FBC New Construction**

Figure E-6. Loss Curve Comparison for Existing and FBC New Construction Runs of House 0013H at Miami in Exposure C

Each of these prescriptive guides is based on wind loads from Chapter 16 of the Standard Building Code. All these guides except the AF&PA guide are based on the 1997 version of the SBC. The AF&PA is based on the 1995 version of the SBC. The difference in the two versions is minor with respect to wind loads.

Each of these prescriptive design documents are allowed by the FBC to be used in wind speed zones specified in Table 2-1 of Section 2. In general, all four documents are allowed for wind speeds of 130 mph (gust wind speed) in Terrain Exposure B. Only the AF&PA document has provisions that allow it to be used up to the 140 mph, Terrain Exposure B zone.

Fenestration Design Pressures in these prescriptive documents are deferred to the SBC97 code, or in the case of the FBC, default to the requirements of Section 1606.1.4 “Protection of Openings”, which require openings be designed according to ASCE 7-98, and if in a wind-borne debris zone, be shuttered or impact resistant. As such, homes constructed according to the prescriptive documents will have the same windows as those done according to ASCE 7-98.

Table E-7 summarizes the key strength variables modeled in this study for the FBC enclosed design and the prescriptive codes.
When you compare the design values of the strap size and the nailing pattern of the 4 prescriptive design documents, one notes that the strap sizes tend to be less than the ASCE 7-98 for equivalent design wind speeds. This difference stems from the change in the load combination in ASCE 7-98 that requires one to consider only 60% of the dead load of the structure counteracting the uplift on the truss. Note, that if the truss were designed with C&C loads as is technically correct, then the difference would be even larger than that shown in Table E-7.

However, from an insurance perspective, the real question is whether these prescriptive designs are equivalent to the ASCE 7–98 designs with respect to loss costs. We ran the prescriptive designs for House 0002H and compared them to the FBC Enclosed designs in Table E-8. This table presents the relativities for a 0% deductible and indicates that there is no real difference in the relativities, and therefore the prescriptive documents may be considered as equivalent (in terms of loss costs) to the FBC designs for those zones where they are allowed. The same conclusion was drawn upon examination of the relativities for 2% and 5%.

Table E-7. Prescriptive Designs of Strap Size and Nailing Pattern for House 0002H

Wind Speed	Exposure	FBC Enclosed		Prescriptive Standards							
				SSTD 10		WPPC[1]		FC&PA		AF&PA	
		Strap[2] (lbf)	Roof Nail Spacing	Strap[2] (lbf)	Roof Nail Spacing	Strap[2] (lbf)	Roof Nail Spacing	Strap[2] (lbf)	Roof Nail Spacing	Strap[2] (lbf)	Roof Nail Spacing
100	B	527	6"x12.0"								
110	B	698	6"x12.0"	253	6"/12"			330	6”/12”	250	6”/12”
120	B	885	6"x12.0"	411	6”/6”	541	6/”12”	503	6”/12”	364	6”/12”
	C	1152	6"x9.6"							364	6”/12”
130	B	1088	6"x9.6"	593	6”/6” ringshank	728	6”/12”	698	6”/12”	492	6”/6”
	C	1402	6"x8.0"								
140	B	1307	6"x8.0"							630	6”/6”
	C	1671	6"x6.9"								
146	C	1843	6"x6.0"								
150	B	1543	6"x6.9"								
	C	1961	6"x6.0"								

[1] The WPPC document does not give any design data for 110 mph zones like the other documents, so the 120 mph specifications have been assumed for lower wind speeds zones.
[2] Straps designed according to MWFRS for interior zone truss.

Table E-8. Loss Relativities for House 0002H by Prescriptive Codes Compared to FBC Enclosed Design (0% Deductible)

Exposure	Wind Speed	ID	FBC Enclosed		Prescriptive Code							
					SSTD 10		WPPC		FC&PA		WFCM	
			No Opening Protection	Opening Protection	No Opening Protection	Opening Protection	No Opening Protection	Opening Protection	No Opening Protection	Opening Protection	No Opening Protection	Opening Protection
B	100	1	0.475		0.477		0.475		0.475			
		2	0.486		0.486		0.486		0.486		0.486	
	110	3	0.491		0.493		0.491		0.493		0.493	
		4	0.493		0.495		0.493		0.493		0.495	
		5	0.502		0.502		0.502		0.502		0.502	
		6	0.479		0.479		0.479		0.479		0.479	
	120	7	0.484		0.481		0.484		0.484		0.484	
		8		0.388		0.387		0.388		0.388		0.388
		9		0.401		0.396		0.401		0.401		0.399
		10		0.394		0.394		0.394		0.396		0.394
		11		0.401		0.397		0.401		0.399		0.399
	130	15		0.390		0.388		0.394		0.394		0.388
		16		0.392		0.392		0.392		0.392		0.392
		17		0.381		0.378		0.383		0.383		0.380
	140	21		0.376								0.374
	150	25		0.372								
C	120	12		0.207								0.208
		13		0.200								0.201
		14		0.207								0.207
	130	18		0.208								

APPENDIX F:

DESIGN CALCULATION FOR HOUSE 0002 BY ASCE 7-98/FBC

APPENDIX F: DESIGN CALCULATIONS FOR HOUSE 0002 BY ASCE 7-98/FBC

This appendix contains one sample set of design calculations for the new construction analysis completed in Section 4 of this report. This sample is for House 0002 done according to ASCE 7-98/Florida Building Code Section 1606.

The dimensions of the building, and other key parameters such as truss spacing are defined on page F-3 under the section called "Geometry of Building". The sizes of the windows, doors, sliders and garage doors are defined on page F-8. Once the configuration of the building is established, these calculations compute the design parameters for the following:

- Roof deck nailing,
- Fenestration design pressures,
- Roof-wall connection design,
- Wood wall design (if applicable), and
- Masonry wall design (if applicable).
- Foundation – Check Sliding/ overturning

The input parameters are the design wind speed and terrain exposure according to the FBC, and the internal pressure condition (Enclosed vs. Partially Enclosed). This particular sample has been prepared for 130 mph design wind speed in Terrain Exposure C for an Enclosed Building condition.

This set of calculations was repeated for each of the FBC combinations of wind speed, terrain exposure, and internal pressure condition listed in Table 2-1 for each of the modeled houses. The results of these calculations are summarized in Tables E-1 through E-4 of this report.

ASCE7-98

Loads on single story building with roof slope 10-30 degrees

Input Parameters

$in0 := (130\ \ C\ \ Enclosed)$

Design Wind Speed = 130 mph
Exposure C
Enclosed

Variables for Exposure

$$\begin{pmatrix} A \\ B \\ C \\ D \end{pmatrix} \equiv \begin{pmatrix} 0 \\ 1 \\ 2 \\ 3 \end{pmatrix}$$

Variables for Enclosed/Part Encl.

$Enclosed \equiv 0$

$PartEnclosed \equiv 1$

Design Parameters

$V := \left|in0^{\langle 0 \rangle}\right| \cdot mph$ $V = 130\,mph$

$I := 1.0$ Importance for Class II Building

$Exp := \left|in0^{\langle 1 \rangle}\right|$ $Case := 1$

Case 1 = C&C and MWFRS for low rise bldgs

$IntPressure := \left|in0^{\langle 2 \rangle}\right|$

Geometry of Building:

$h := 16 \cdot ft$ Average ht of building (mean roof height)

$\theta := atan\left(\frac{6}{12}\right)$ $\theta = 26.57\,deg$ roof slope

$o := 1.5 \cdot ft$ overhang width

$o_g := 1.5 \cdot ft$ overhang at "gable" end

$W := 50ft + 2 \cdot o$ dimensions of building

$L := 60ft + 2 \cdot o_g$

$\Delta := 2ft$ Truss spacing

Roof cover: Shingle

$h_{wall} := 9 \cdot ft + 4 \cdot in$ Height of Wall

Dead load of roof

$DL_{roof} := 9 \cdot psf$ Hip roof, shingle, trusses, underlayment (from SBC Appendix A)

$DL_{sheath} := (0.5 \cdot in) \cdot \left(\frac{0.4psf}{.125 \cdot in}\right)$ $DL_{sheath} = 1.6\,psf$

Dead load of roof is composed of following: Truss/Sheathing (7 psf), Tile (10psf). If shingles are used, use 2 psf instead of 10 psf.

$L_{attic} := 30 \cdot psf$ SBC Table 1604.1

$L_{floor} := 40 \cdot psf$

$L_{roof} := 16 \cdot psf$

$\phi := 0.6$ Fraction of DeadLoad used in combination with Wind Load

$DL_{wall} := \begin{pmatrix} 10 \\ 55 \end{pmatrix} \cdot psf$ Wood Frame wall weight
Masonry Wall Weight

$DL_{misc} := 15 \cdot psf$ Miscellaneous: Contents, carpet, cabinets, fixtures)

AREAS: Roof - Hip Roof

Vertical Projected Area: wind perpendicular to ridge

$h_{ridge} := \frac{W}{2} \cdot \tan(\theta)$ $\qquad h_{ridge} = 13.25\,ft$

$VPA_{\Gamma} := \frac{h_{ridge}}{2} \cdot [L + (L - W)]$ $\qquad VPA_{\Gamma} = 483.62\,ft^2$

Vertical Projected Area: wind parallel to ridge

$VPA_{ll} := \frac{W \cdot h_{ridge}}{2}$ $\qquad VPA_{ll} = 351.12\,ft^2$

Horizontal Projected Area:

$HPA := W \cdot L$ $\qquad HPA = 3339\,ft^2$

AREAS: Walls

Vertical Projected Area: : wind perpendicular to ridge - half of horizontal load transferred directly to foundation

$VPA_{wall\Gamma} := \frac{h_{wall}}{2} \cdot L$ $\qquad VPA_{wall\_ll} := \frac{h_{wall}}{2} \cdot W$

$VPA_{wall\Gamma} = 294\,ft^2$ $\qquad VPA_{wall\_ll} = 247.33\,ft^2$

Dynamic Wind Pressure

Terrain Exposure Constants

$$z_g := \begin{pmatrix} 1500 \cdot ft \\ 1200 \cdot ft \\ 900 \cdot ft \\ 700 \cdot ft \end{pmatrix} \quad \alpha := \begin{pmatrix} 5.0 \\ 7.0 \\ 9.5 \\ 11.5 \end{pmatrix} \quad h_{min} := \begin{pmatrix} 60 \\ 30 \\ 15 \\ 7 \end{pmatrix} \cdot ft$$

Exposures = A,B,C,D

$$h_{min} := \begin{cases} \begin{pmatrix} 100 \\ 30 \\ 15 \\ 15 \end{pmatrix} \cdot ft & \text{if } Case = 1 \\ \begin{pmatrix} 15 \\ 15 \\ 15 \\ 15 \end{pmatrix} \cdot ft & \text{otherwise} \end{cases}$$

$$K_z(h) := \begin{cases} 2.01 \cdot \left(\dfrac{15 \cdot ft}{z_{g_{Exp}}} \right)^{\frac{2}{\alpha_{Exp}}} & \text{if } h < 15 \cdot ft \\ 2.01 \cdot \left(\dfrac{h_{min_{Exp}}}{z_{g_{Exp}}} \right)^{\frac{2}{\alpha_{Exp}}} & \text{if } h < h_{min_{Exp}} \\ 2.01 \cdot \left(\dfrac{h}{z_{g_{Exp}}} \right)^{\frac{2}{\alpha_{Exp}}} & \text{otherwise} \end{cases}$$

$K_z(h) = 0.86$

$K_{zt} := 1.0$ No topographic speedup

$K_d := 0.85$ Directionality factor (0.85 used when doing combination loads - with dead load)

$$q_h := .00256 \frac{slug}{2.15111 ft^3} \cdot K_z(h) \cdot K_{zt} \cdot K_d \cdot V^2 \cdot I \qquad q_h = 31.64 psf$$

Dynamic Wind Pressure

Internal Pressure coefficient

$$GC_{pi} := \begin{cases} \begin{pmatrix} -0.18 \\ 0.18 \end{pmatrix} & \text{if } IntPressure = Enclosed \\ \begin{pmatrix} -0.55 \\ 0.55 \end{pmatrix} & \text{if } IntPressure = PartEnclosed \\ \begin{pmatrix} -20 \\ 20 \end{pmatrix} & \text{otherwise} \end{cases}$$

$$GC_{pi} = \begin{pmatrix} -0.18 \\ 0.18 \end{pmatrix}$$

internal pressure range variable

$posneg := 0..1$

← Dummy value in Case Int Pressure is invalid

Gust Factor:

Terrain Exposure Constants from Table 6-4

$$l := \begin{pmatrix} 180 \\ 320 \\ 500 \\ 650 \end{pmatrix} \cdot ft \qquad \varepsilon := \begin{pmatrix} \frac{1}{2} \\ \frac{1}{3} \\ \frac{1}{5} \\ \frac{1}{8} \end{pmatrix} \qquad c := \begin{pmatrix} 0.45 \\ 0.3 \\ 0.2 \\ 0.15 \end{pmatrix} \qquad z_{min} := \begin{pmatrix} 60 \\ 30 \\ 15 \\ 7 \end{pmatrix} \cdot ft$$

$z_e := \begin{pmatrix} 0.6 \cdot h \\ z_{min_{Exp}} \end{pmatrix}$ $z_e := \max(z_e)$ $z_e = 15\,ft$ Equivalent height of structure

$I_z := c_{Exp} \cdot \left(\frac{33 \cdot ft}{z_e}\right)^{\frac{1}{6}}$ $I_z = 0.23$ Turbulence Intensity (eqn 6-3)

$L_z := l_{Exp} \cdot \left(\frac{z_e}{33 \cdot ft}\right)^{\varepsilon_{Exp}}$ $L_z = 427.06\,ft$ Integral Length Scale of Turbulence (Eqn 6-5)

$Q := \sqrt{\frac{1}{1 + 0.63 \cdot \left(\frac{W + h}{L_z}\right)^{0.63}}}$ $Q = 0.91$ Background Response (Eqn 6-4)

$g_Q := 3.4$ $g_v := 3.4$

$G := 0.925 \cdot \left(\frac{1 + 1.7 \cdot g_Q \cdot I_z \cdot Q}{1 + 1.7 \cdot g_v \cdot I_z}\right)$ $G = 0.88$ Gust Factor (Eqn 6-2)

External Pressure Coefficients C&C loads: Figure 6-5B

Limits of External Pressure Coefficients for each Zone in C&C loads
(first row neg coefficients, second row positive coefficents)

$GCp_1 := \begin{pmatrix} -0.9 & -0.8 \\ 0.5 & 0.3 \end{pmatrix}$ 10SF neg 100SF neg / 10SF pos 100SF pos $Alim_1 := (10 \;\; 100) \cdot ft^2$

ASCE7-98: Figure 6-5B Gable/Hip Roofs 10 deg <θ< 30 deg

$GCp_2 := \begin{pmatrix} -2.1 & -1.4 \\ 0.5 & 0.3 \end{pmatrix}$ $Alim_2 := (10 \;\; 100) \cdot ft^2$

$GCp_3 := \begin{pmatrix} -2.1 & -1.4 \\ 0.5 & 0.3 \end{pmatrix}$ $Alim_3 := (10 \;\; 100) \cdot ft^2$

$GCp_4 := \begin{pmatrix} -1.1 & -0.8 \\ 1.0 & 0.7 \end{pmatrix}$ $Alim_4 := (10 \;\; 500) \cdot ft^2$

ASCE7-98: Figure 6-5A

$GCp_5 := \begin{pmatrix} -1.4 & -0.8 \\ 1.0 & 0.7 \end{pmatrix}$ $Alim_5 := (10 \;\; 500) \cdot ft^2$

overhang coefficients

$GCp_6 := \begin{pmatrix} -2.2 & -2.2 \\ 0 & 0 \end{pmatrix}$ Zone 2 $Alim_6 := (10 \;\; 100) \cdot ft^2$

$GCp_7 := \begin{pmatrix} -3.7 & -2.5 \\ 0 & 0 \end{pmatrix}$ Zone 3 $Alim_7 := (10 \;\; 100) \cdot ft^2$

$$slope_{GCp}(Zone) := \frac{\left(GCp_{Zone}\right)^{\langle 1 \rangle} - \left(GCp_{Zone}\right)^{\langle 0 \rangle}}{\log\left[\frac{\left|\left(Alim_{Zone}\right)^{\langle 1 \rangle}\right|}{ft^2}\right] - \log\left[\frac{\left|\left(Alim_{Zone}\right)^{\langle 0 \rangle}\right|}{ft^2}\right]}$$

$$GC_p(Area, Zone) := \begin{cases} \left(GCp_{Zone}\right)^{\langle 0 \rangle} & \text{if } Area < \left|\left(Alim_{Zone}\right)^{\langle 0 \rangle}\right| \\ \left(GCp_{Zone}\right)^{\langle 1 \rangle} & \text{if } Area > \left|\left(Alim_{Zone}\right)^{\langle 1 \rangle}\right| \\ \left(slope_{GCp}(Zone)\right) \cdot \left[\log\left(\frac{Area}{ft^2}\right) - \log\left[\frac{\left|\left(Alim_{Zone}\right)^{\langle 0 \rangle}\right|}{ft^2}\right]\right] + \left(GCp_{Zone}\right)^{\langle 0 \rangle} & \text{otherwise} \end{cases}$$

For Example:

$GC_p\left(10 \cdot ft^2, 4\right) = \begin{pmatrix} -1.1 \\ 1 \end{pmatrix}$ $GC_p\left(200 \cdot ft^2, 5\right) = \begin{pmatrix} -0.94 \\ 0.77 \end{pmatrix}$ $GC_p\left(100 \cdot ft^2, 1\right) = \begin{pmatrix} -0.8 \\ 0.3 \end{pmatrix}$

$GC_p\left(200 \cdot ft^2, 4\right) = \begin{pmatrix} -0.87 \\ 0.77 \end{pmatrix}$ $GC_p\left(10 \cdot ft^2, 6\right) = \begin{pmatrix} -2.2 \\ 0 \end{pmatrix}$

Window Design Pressure

The following input table was imported from an excel sheet that had a list of fens for this building. Each column represents the width, height, area, and zone of each fen respectively.

Width Height $Size := 2$ $Zone := 3$ $Fraction := 4$

Fen :=

	0	1	2	3	4
0	4	5	20	4	1
1	3	5	15	4	1
2	2.7	7	18.9	4	1
3	8	8	32	4	1
4	16	8	32	4	1
5	3	5	15	5	1
6	6	5	15	4	1
7	5	5	25	5	1
8	5	5	25	5	1
9	3	5	15	4	1
10	2	5	10	5	1
11	2	5	10	4	1
12	16	7	85.3	45	0.22
13	3	7	21	4	1
14	3	7	21	4	1
15	5	7	35	4	1
16	3	7	21	4	1
17	6	3	18	4	1
18	6	8	48	4	1
19	5	7	35	5	1

When Zone = 45, Fraction represents portion of fen in Zone 5.

Garage door ratio in Zone 5 is 24.5 SF of 112 SF

Garage Effective Area set by considering single spanning panel that is 16ft wide.

$rows(Fen) = 20$

$j := 0 .. rows(Fen) - 1$

$$DP^{\langle j \rangle} := \begin{cases} q_h \cdot \left(GC_p\left(\overrightarrow{\left[\left(Fen^{\langle Size \rangle} \right)_j \cdot ft^2 \right]}, \overrightarrow{\left(Fen^{\langle Zone \rangle} \right)_j} \right) + GC_{pi} \right) & \text{if } \left(Fen^{\langle Zone \rangle} \right)_j \neq 45 \\ \left[\begin{array}{l} q_h \cdot \left(GC_p\left(\overrightarrow{\left[\left(Fen^{\langle Size \rangle} \right)_j \cdot ft^2 \right]}, 5 \right) + GC_{pi} \right) \cdot \left(Fen^{\langle Fraction \rangle} \right)_j \ldots \\ + q_h \cdot \left(GC_p\left(\overrightarrow{\left[\left(Fen^{\langle Size \rangle} \right)_j \cdot ft^2 \right]}, 4 \right) + GC_{pi} \right) \cdot \left[1 - \left(Fen^{\langle Fraction \rangle} \right)_j \right] \end{array} \right] & \text{otherwise} \end{cases}$$

Effective Area of fenestrations are set according to the area of the element resisting the load, as opposed to the area of the entire fenestration. For example, a sliding glass door is made of 3 doors spanning vertically, each door is 4x8 ft. The doors do not transfer wind load horizontally, therefore the wind loads are correlated only over the single door, and thus instead of an effective area of 96 square feet, the effective area is 32 square feet.

DP =

	0	1	2	3	4	5	6	7	8	9
0	-38.82	-39.52	-38.96	-37.68	-37.68	-48.03	-39.52	-45.55	-45.55	-39.52
1	35.66	36.36	35.8	34.52	34.52	36.36	36.36	35.12	35.12	36.36

psf

for Sliding Glass door : Design pressures are: $DP^{\langle 4 \rangle} = \begin{pmatrix} -37.68 \\ 34.52 \end{pmatrix} psf$

Design of Nailing Pattern for Roof Deck

Tributary area for single fastener: $Area := 10 \cdot ft^2$

Zone1	Zone 2	Zone 3
$GC_p(Area,1) = \begin{pmatrix} -0.9 \\ 0.5 \end{pmatrix}$	$GC_p(Area,2) = \begin{pmatrix} -2.1 \\ 0.5 \end{pmatrix}$	$GC_p(Area,3) = \begin{pmatrix} -2.1 \\ 0.5 \end{pmatrix}$

Design load: Zone2

$p_{single} := q_h \cdot (GC_p(Area,2) + GC_{pi})$ $\qquad p_{single} = \begin{pmatrix} -72.15 \\ 21.52 \end{pmatrix} psf$

Tributary area for single sheet of plywood fastener: $Area := 32 \cdot ft^2$

One 4x8ft sheet of plywood/OSB = 32 FT tributary area

Zone1	Zone 2	Zone 3
$GC_p(Area,1) = \begin{pmatrix} -0.85 \\ 0.4 \end{pmatrix}$	$GC_p(Area,2) = \begin{pmatrix} -1.75 \\ 0.4 \end{pmatrix}$	$GC_p(Area,3) = \begin{pmatrix} -1.75 \\ 0.4 \end{pmatrix}$

$p_{panel} := q_h \cdot (GC_p(Area,2) + GC_{pi})$ $\qquad p_{panel} = \begin{pmatrix} -60.96 \\ 18.32 \end{pmatrix} psf$

Resistance of single 8d Nail

Load Case : Wind + 60% of dead load

$q_r := 41 \cdot \frac{lbf}{in}$ 8d common nail, NDS 1997, page 30, diameter 0.131", specific Gravity 0.55 (Southern Pine)

$l_{nail} := 2.5in$ length of nail, 8d

$t := .5 \cdot in$ Plywood thickness = 1/2" (min thickness of code)

$l_p := l_{nail} - t$ $\quad l_p = 2\,in$ penetration length

Southern Pine SG - 0.55 on page 29, Table 12A of NDS-S97

$C_D := 1.6$ Duration factor for short term loads - wind = 10 minutes

$C_m := 1.0$ Condition Factor = assume that wood moisture content at time of construction is same as long term value

$R_{nail} := q_r \cdot l_p \cdot C_D \cdot C_m$ $\qquad R_{nail} = 131.2\,lbf$

Maximum Spacing for 8d nail:

$A_t := \frac{R_{nail}}{\left(\left|p_{single_0} + 0.6 \cdot DL_{sheath}\right| \cdot 2 \cdot ft\right)}$ $A_t = 11.06\,in$ maximum required spacing of fasteners

Select nailing pattern that meets max spacing criteria

practical number of nails that meets nailing spacing criteria listed above (Zone 2/3)

$ceil(linterp(s_{possible}, N_{possible}, A_t)) = 6$

lookup nailing pattern to meet Zone2/3

$II_s := floor(linterp(s_{possible}, II, A_t))$

$s_i := s_{possible_{II_s}}$

spacing, nails

NailSched =

4.36	12
4.8	11
5.33	10
6	9
6.86	8
8	7
9.6	6
12	5
16	4
24	3
48	2

USE the following spacing:

$s_e := 6in$ edge spacing $s_i = 9.6\,in$ interior spacing

$N_{nails} := 2 \cdot \left(\frac{48in}{s_e} + 1\right) + 3 \cdot \left(\frac{48in}{s_i} + 1\right)$ $N_{nails} = 36$

Check whole panel resistance

$L_{panel} := \left(\left|p_{panel_0} + 0.6 \cdot DL_{sheath}\right|\right) \cdot 32ft^2$ $L_{panel} = 1919.98\,lbf$ uplift

$R_{total} := R_{nail} \cdot N_{nails}$ $R_{total} = 4723.2\,lbf$

$Status_{RoofNail} := R_{total} > L_{panel}$ $Status_{RoofNail} = 1$ PASS = 1, FAIL = 0

ROOF STRAPS DESIGN (Uplift): Design of Typical Truss at Center of Building

Several methods of calculating the uplift on the truss have been explored here. The HURLOSS roof-strap model simulates failure of the entire roof assembly as a whole, and not any one specific truss connection. Therefore, strap size in model is based on a strap that is representative of the majority of the connections, and therefore is based on section at middle of structure.

1. The first method is considering the Component & Cladding (C&C) loads that are acting on a single truss in the middle of the roof.
2. The second method is summing up the total Main Wind Force Resisting System (MWFRS) load pattern for a truss at the center of the building.

In addition, for comparison to prescriptive documents, the corner truss load has also be considered by the MWFRS load method.

Assume straps on 2 long edges of building only, regardless of hip or gable configuration.

Edge zone

$a := \min\left(\begin{pmatrix} 0.1 \cdot W \\ 0.1 \cdot L \\ 0.4 \cdot h \end{pmatrix}\right) \quad a := \max\left(\begin{pmatrix} a \\ 0.04 \cdot W \\ 0.04 \cdot L \\ 3 \cdot ft \end{pmatrix}\right) \qquad a = 5.3\,ft$

Notes:
1. HUD RSDG 2000 and SSTD10 specifies that roof uplift for design of rood tie-downs should be determined using "MWFRS" loads

$l_r := \dfrac{W}{2 \cdot \cos(\theta)} \qquad l_r = 29.63\,ft$ length of top chord of truss

$a_\theta := \dfrac{a}{\cos(\theta)}$ length of edge zones along roof slope - assume that a in ASCE7 figures are widths in plan.

Method 1: Center Roof Truss Design based on Components and Cladding loads from ASCE 7-98

Effective wind area of a truss equals maximum of actual area and span times 1/3 span length

$A_{eff} := \left(\begin{pmatrix} W \cdot \Delta \\ W \cdot \dfrac{W}{3} \end{pmatrix}\right) \qquad A_{eff} = \begin{pmatrix} 106 \\ 936.33 \end{pmatrix} ft^2$

$A_{eff} := \max(A_{eff})$

$A_{eff} = 936.33\,ft^2$

External Gust Factors

$GC_p(A_{eff}, 1) = \begin{pmatrix} -0.8 \\ 0.3 \end{pmatrix}$

$GC_p(A_{eff}, 2) = \begin{pmatrix} -1.4 \\ 0.3 \end{pmatrix}$

$GC_p(A_{eff}, 3) = \begin{pmatrix} -1.4 \\ 0.3 \end{pmatrix}$

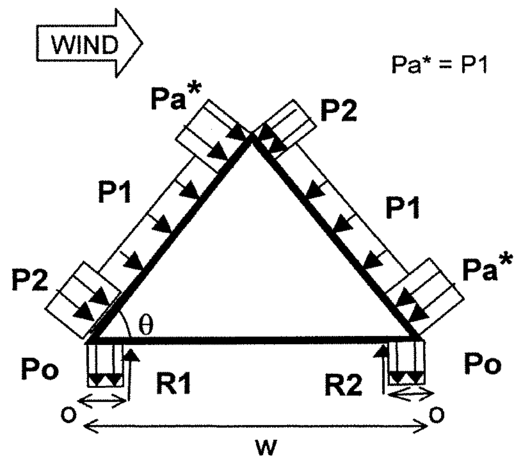
$k := 1 .. 3 \qquad p_k := \left(GC_p(A_{eff}, k)_0 + GC_{pi_0}\right) \cdot q_h$

$p = \begin{pmatrix} 0 \\ -31.01 \\ -50 \\ -50 \end{pmatrix} psf$ Design Pressures for Zones 1, 2, and 3

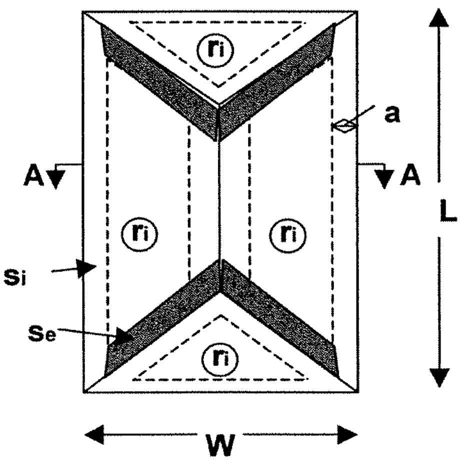
Overhang pressures $\quad p_o := \left(GC_p(A_{eff}, 6)_0\right) \cdot q_h \qquad GC_p(A_{eff}, 6) = \begin{pmatrix} -2.2 \\ 0 \end{pmatrix} \qquad p_o = -69.62\,psf$

WIND Perpendicular to Ridge: Loading pattern according to ASCE 7-95 guide by K. Metha

Set pa equal to p1, because ASCE7-95 guidebook indicates that truss loads should follow patterns where Zone2 is not applied simultaneously to all locations according to wind tunnel tests.



Pa* = P1



Note pressures on roof shown in positive sense

Sum Moments

$$R_1 := \frac{\Delta}{(W-2\cdot o)}\cdot\left[\begin{array}{l} p_o\cdot\frac{o}{\cos(\theta)}\cdot\cos(\theta)\cdot\left(W-o-\frac{o}{2}\right)\ \ldots \\ +p_2\cdot\left(a_\theta-\frac{o}{\cos(\theta)}\right)\cdot\cos(\theta)\cdot\left(W-o-\frac{a-o}{2}-o\right)\ \ldots \\ +p_1\cdot(l_r-a_\theta)\cdot\cos(\theta)\cdot\left[W-o-a-(l_r-a_\theta)\cdot\frac{1}{2}\cdot\cos(\theta)\right]\ \ldots \\ +p_2\cdot a_\theta\cdot\cos(\theta)\cdot\left(\frac{W}{2}-o-\frac{a}{2}\right)\ \ldots \\ +p_1\cdot(l_r-a_\theta)\cdot\cos(\theta)\cdot\left[(l_r-a_\theta)\cdot\frac{1}{2}\cdot\cos(\theta)-o\right]\ \ldots \\ +\left[-p_o\cdot\frac{o}{\cos(\theta)}\cdot\sin(\theta)\cdot\left(\frac{o}{2\cdot\cos(\theta)}\cdot\sin(\theta)\right)\right]\ \ldots \\ +\left[-p_2\cdot\left(a_\theta-\frac{o}{\cos(\theta)}\right)\cdot\left[a_\theta-\frac{1}{2}\cdot\left(a_\theta-\frac{o}{\cos(\theta)}\right)\right]\cdot\sin(\theta)^2\right]\ \ldots \\ +\left[-p_1\cdot(l_r-a_\theta)\cdot\left[\frac{1}{2}\cdot(l_r+a_\theta)\right]\cdot\sin(\theta)^2\right]\ \ldots \\ +\left[p_2\cdot(a_\theta)\cdot\left(l_r-\frac{1}{2}\cdot a_\theta\right)\cdot\sin(\theta)^2\right]\ \ldots \\ +\left[p_1\cdot(l_r-a_\theta)\cdot\left[\frac{1}{2}\cdot(l_r-a_\theta)\right]\cdot\sin(\theta)^2\right]\ \ldots \\ +\phi\cdot DL_{roof}\cdot W\cdot\left(\frac{W}{2}-o\right) \end{array}\right]$$

Dead load factor, ASD

$\phi = 0.6$

$R_1 = -1724.85\ \text{lbf}$

Sum Forces in Vertical

$$R_2 := \left[\left[\left[\begin{array}{l}\left(p_2\cdot a_\theta\cdot\Delta\cdot\cos(\theta)\right)+\left[p_2\cdot\left(a_\theta-\frac{o}{\cos(\theta)}\right)\cdot\Delta\cdot\cos(\theta)\right]\ \ldots \\ +2\cdot\Delta\cdot p_1\cdot(l_r-a_\theta)\cdot\cos(\theta)+\Delta\cdot p_o\cdot\frac{o}{\cos(\theta)}\cdot\cos(\theta)\end{array}\right]\right]-R_1+\phi\cdot DL_{roof}\cdot\Delta\cdot W\right]$$

$R_2 = -1451.33\ \text{lb}$

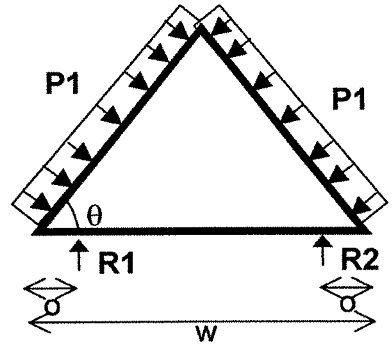
WIND Parallel to Ridge

$$R_3 := \frac{\Delta}{W - 2\cdot o}\cdot\left[\begin{array}{l} p_1\cdot l_r\cdot\cos(\theta)\cdot\left[\left(W - o - \frac{l_r}{2}\cdot\cos(\theta)\right) + \left(\frac{l_r}{2}\cdot\cos(\theta) - o\right)\right] \dots \\ + \phi\cdot DL_{roof}\cdot W\cdot\left(\frac{W}{2} - o\right)\end{array}\right]$$

$$R_4 := 2\cdot p_1\cdot l_r\cdot\Delta\cdot\cos(\theta) - R_3 + \phi\cdot DL_{roof}\cdot\Delta\cdot W$$

$R_3 = -1357.4\,\text{lbf}$

$R_4 = -1357.4\,\text{lbf}$



Method 2: Check MWFRS loading conditions:

There are 4 external loading conditions for the upper roof and two internal pressure conditions

Corner 1: CASE A wind perpendicular to ridge
Corner 1: CASE B wind parallel to ridge
Corner 2: CASE A wind perpendicular to 'imaginary ridge'
Corner 2: CASE B wind parallel to 'imaginary ridge'

Figure 6-4: Walls and Gable Roof

CASE A Table from Figure 6-4

$$roofAng := \begin{pmatrix} 0 \\ 5 \\ 20 \\ 30 \\ 45 \\ 90 \end{pmatrix} \quad casea := \begin{pmatrix} 0.40 & -0.69 & -0.37 & -0.29 & 0.61 & -1.07 & -0.53 & -0.43 \\ 0.40 & -0.69 & -0.37 & -0.29 & 0.61 & -1.07 & -0.53 & -0.43 \\ 0.53 & -0.69 & -0.48 & -0.43 & 0.80 & -1.07 & -0.69 & -0.64 \\ 0.56 & 0.21 & -0.43 & -0.37 & 0.69 & 0.27 & -0.53 & -0.48 \\ 0.56 & 0.21 & -0.43 & -0.37 & 0.69 & 0.27 & -0.53 & -0.48 \\ 0.56 & 0.56 & -0.37 & -0.37 & 0.69 & 0.69 & -0.48 & -0.48 \end{pmatrix}$$

$zoneA := 0..7$

range of values in CASE A table

$zoneB := 0..11$

range of values in CASE B table

$$GC_{pfA1_{zoneA}} := \text{linterp}\left(roofAng, casea^{\langle zoneA\rangle}, \frac{\theta}{deg}\right)$$

Interpolated for roof slope $\theta = 26.57\,\text{deg}$

$$GC_{pfA2_{zoneA}} := \text{linterp}\left(roofAng, casea^{\langle zoneA\rangle}, 0\right)$$

Roof Slope equal 0, See Note 2 in Figure 6-4

Corner 1 $GC_{pfA1}^{T} = (0.55\ \ -0.1\ \ -0.45\ \ -0.39\ \ 0.73\ \ -0.19\ \ -0.58\ \ -0.53)$

Corner 2 $GC_{pfA2}^{T} = (0.4\ \ -0.69\ \ -0.37\ \ -0.29\ \ 0.61\ \ -1.07\ \ -0.53\ \ -0.43)$

CASE B from Figure 6-4

Corner 1 $GC_{pfB1} := (-0.45\ \ -0.69\ \ -0.37\ \ -0.45\ \ 0.4\ \ -0.29\ \ -0.48\ \ -1.07\ \ -0.53\ \ -0.48\ \ 0.61\ \ -0.43)^{T}$

Corner 2 $GC_{pfB2} := GC_{pfB1}$

Pressures

$$p_{A1_{posneg,zoneA}} := q_h \cdot \left(GC_{pfA1_{zoneA}} + GC_{pi_{posneg}}\right) \qquad p_{B1_{posneg,zoneB}} := q_h \cdot \left(GC_{pfB1_{zoneB}} + GC_{pi_{posneg}}\right)$$

$$p_{A2_{posneg,zoneA}} := q_h \cdot \left(GC_{pfA2_{zoneA}} + GC_{pi_{posneg}}\right) \qquad p_{B2} := p_{B1}$$

$$p_{A1} = \begin{pmatrix} 11.7 & -8.83 & -19.85 & -18.06 & 17.33 & -11.72 & -24.21 & -22.62 \\ 23.09 & 2.56 & -8.45 & -6.66 & 28.73 & -0.33 & -12.81 & -11.23 \end{pmatrix} \text{psf}$$

Note: No Overhang Loads as part of MWFRS

$p_{B1} =$

-19.94	-27.53	-17.4	-19.94	6.96	-14.87	-20.89	-39.56	-22.47	-20.89	13.61	-19.3
-8.54	-16.14	-6.01	-8.54	18.35	-3.48	-9.49	-28.16	-11.08	-9.49	25	-7.91

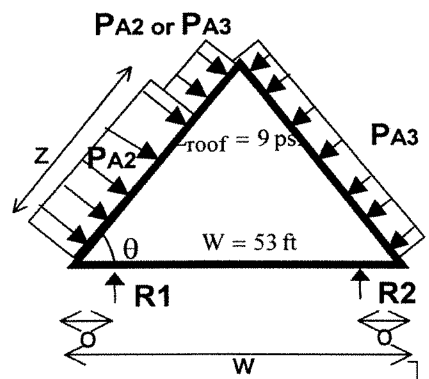
psf

$$p_{A2} = \begin{pmatrix} 6.96 & -27.53 & -17.4 & -14.87 & 13.61 & -39.56 & -22.47 & -19.3 \\ 18.35 & -16.14 & -6.01 & -3.48 & 25 & -28.16 & -11.08 & -7.91 \end{pmatrix} \text{psf}$$

z = width of zone 2 on roof parallel to wind direction, varies for some cases

$$z := \left(\begin{pmatrix} 0.5 \cdot W \\ 2.5 \cdot h \end{pmatrix}\right) \quad z = \begin{pmatrix} 26.5 \\ 40 \end{pmatrix} \text{ft} \quad z := \min(z) \quad z = 26.5 \text{ ft}$$

CASE A Corner 1 Sum moments about R2 reaction of load distribution



Note: Figure 6-4 indicates that zone 2 pressure extends for distance of z only, if zone 2 pressure is negative

$$p_{A1}^{\langle A2 \rangle} = \begin{pmatrix} -8.83 \\ 2.56 \end{pmatrix} \text{psf} \qquad p_{A1}^{\langle A3 \rangle} = \begin{pmatrix} -19.85 \\ -8.45 \end{pmatrix} \text{psf}$$

$$R_{1_{posneg}} := \frac{1}{W - 2 \cdot o} \cdot \left[\begin{array}{l} \left[\left[\left(p_{A1}^{\langle A2 \rangle}\right)_{posneg} \cdot z \cdot \Delta \cos(\theta) \cdot \left(W - o - \frac{z}{2} \cdot \cos(\theta)\right) \right] \ldots \right. \\ + \left[\begin{array}{ll} \left(p_{A1}^{\langle A3 \rangle}\right)_{posneg} & \text{if } \left(p_{A1}^{\langle A2 \rangle}\right)_{posneg} < 0 \\ \left(p_{A1}^{\langle A2 \rangle}\right)_{posneg} & \text{otherwise} \end{array} \right] \cdot (l_r - z) \cdot \Delta \cos(\theta) \cdot \left[\begin{array}{l} \left(\frac{W}{2} - o\right) \ldots \\ + \left[\left(\frac{l_r - z}{2}\right) \cdot \cos(\theta) \right] \end{array} \right] \ldots \\ \left. + \left(p_{A1}^{\langle A3 \rangle}\right)_{posneg} \cdot l_r \cdot \Delta \cos(\theta) \cdot \left(\frac{l_r}{2} \cdot \cos(\theta) - o\right) \right] \ldots \\ + \left[\begin{array}{l} -\left(p_{A1}^{\langle A2 \rangle}\right)_{posneg} \cdot z \cdot \Delta \cdot \sin(\theta) \cdot \left(\frac{z}{2} \cdot \sin(\theta)\right) \ldots \\ + \left[\begin{array}{ll} -\left(p_{A1}^{\langle A3 \rangle}\right)_{posneg} & \text{if } \left(p_{A1}^{\langle A2 \rangle}\right)_{posneg} < 0 \\ -\left(p_{A1}^{\langle A2 \rangle}\right)_{posneg} & \text{otherwise} \end{array} \right] \cdot (l_r - z) \cdot \Delta \cdot \sin(\theta) \cdot \left(z + \frac{l_r - z}{2}\right) \cdot \sin(\theta) \ldots \\ + \left(p_{A1}^{\langle A3 \rangle}\right)_{posneg} \cdot l_r \cdot \Delta \cdot \sin(\theta) \cdot \left(\frac{l_r}{2} \cdot \sin(\theta)\right) \end{array} \right] \ldots \\ + \phi \cdot DL_{roof} \cdot W \cdot \Delta \cdot \left(\frac{W}{2} - o\right) \end{array} \right]$$

Sum forces in vertical direction

$$R_{2_{posneg}} := \left(p_{A1}{}^{\langle A2\rangle}\right)_{posneg} \cdot z \cdot \Delta \cdot \cos(\theta) \; ...$$
$$+ \left[\begin{array}{ll} \left(p_{A1}{}^{\langle A3\rangle}\right)_{posneg} & \text{if } \left(p_{A1}{}^{\langle A2\rangle}\right)_{posneg} < 0 \\ \left(p_{A1}{}^{\langle A2\rangle}\right)_{posneg} & \text{otherwise} \end{array} \right] \cdot (l_r - z) \cdot \Delta \cdot \cos(\theta) \; ...$$
$$+ \left(p_{A1}{}^{\langle A3\rangle}\right)_{posneg} \cdot l_r \cdot \Delta \cdot \cos(\theta) \; ...$$
$$+ -R_{1_{posneg}} + \phi \cdot DL_{roof} \cdot \Delta \cdot W$$

$$R_1 = \begin{pmatrix} -382.61 \\ 245.97 \end{pmatrix} \text{lbf} \qquad R_2 = \begin{pmatrix} -626.65 \\ 13.95 \end{pmatrix} \text{lbf}$$

$$R_T := \text{stack}(R_1, R_2) \qquad R_{MWF_0} := \min((R_T)) \qquad R_{MWF_0} = -626.65\,\text{lbf}$$

<u>CASE B Corner 1</u>

$$R_1 := \frac{1}{W - 2 \cdot o} \cdot \left[\begin{array}{l} \left[\begin{array}{l} p_{B1}{}^{\langle B2\rangle} \cdot l_r \cdot \Delta \cos(\theta) \cdot \left(W - o - \frac{l_r}{2} \cdot \cos(\theta) \right) \; ... \\ + p_{B1}{}^{\langle B3\rangle} \cdot l_r \cdot \Delta \cos(\theta) \cdot \left(\frac{l_r}{2} \cdot \cos(\theta) - o \right) \end{array} \right] ... \\ + \left[\begin{array}{l} -p_{B1}{}^{\langle B2\rangle} \cdot l_r \cdot \Delta \cdot \sin(\theta) \cdot \left(\frac{l_r}{2} \cdot \sin(\theta) \right) \; ... \\ + p_{B1}{}^{\langle B3\rangle} \cdot l_r \cdot \Delta \cdot \sin(\theta) \cdot \left(\frac{l_r}{2} \cdot \sin(\theta) \right) \end{array} \right] ... \\ + \phi \cdot DL_{roof} \cdot W \cdot \Delta \cdot \left(\frac{W}{2} - o \right) \end{array} \right]$$

$$p_{B1}{}^{\langle B2\rangle} = \begin{pmatrix} -27.53 \\ -16.14 \end{pmatrix} \text{psf}$$

$$p_{B1}{}^{\langle B3\rangle} = \begin{pmatrix} -17.4 \\ -6.01 \end{pmatrix} \text{psf}$$

$$R_1 = \begin{pmatrix} -1011.24 \\ -407.47 \end{pmatrix} \text{lbf}$$

$$R_2 := \left(p_{B1}{}^{\langle B2\rangle} \cdot l_r \cdot \Delta \cdot \cos(\theta)\right) + \left(p_{B1}{}^{\langle B3\rangle} \cdot l_r \cdot \Delta \cdot \cos(\theta)\right) - R_1 + DL_{roof} \cdot \Delta \cdot W$$

$$R_2 = \begin{pmatrix} -416.31 \\ 187.47 \end{pmatrix} \text{lbf}$$

$$R_T := \text{stack}(R_1, R_2) \qquad R_{MWF_1} := \min((R_T)) \qquad R_{MWF_1} = -1011.24\,\text{lbf}$$

CASE A Corner 2

Assume truss is on windward side of imaginary line drawn for distance z from windward edge. All wind zones are Zone 2 or 2E.

$$R_1 := \frac{1}{W - 2\cdot o}\cdot\left[\left[\left[p_{A2}^{\langle A2E\rangle}\cdot 2\cdot a_\theta\cdot\Delta\cos(\theta)\cdot\left(W - o - a_\theta\cdot\cos(\theta)\right)\right]\ldots + \left[p_{A2}^{\langle A2\rangle}\cdot\left(l_r - 2\cdot a_\theta\right)\cdot\Delta\cos(\theta)\cdot\left[W - o - 2\cdot a_\theta\cdot\cos(\theta) - \frac{\left(l_r - 2\cdot a_\theta\right)}{2}\cdot\cos(\theta)\right]\right]\ldots + p_{A2}^{\langle A2\rangle}\cdot l_r\cdot\Delta\cos(\theta)\cdot\left(\frac{l_r}{2}\cdot\cos(\theta) - o\right)\right]\ldots + \left[\left[-p_{A2}^{\langle A2E\rangle}\cdot\left(2\cdot a_\theta\right)\cdot\Delta\cdot\sin(\theta)\cdot\left(a_\theta\cdot\sin(\theta)\right)\right]\ldots + \left[-p_{A2}^{\langle A2\rangle}\cdot\left(l_r - 2\cdot a_\theta\right)\cdot\Delta\cdot\sin(\theta)\cdot\left[\left(2\cdot a_\theta + \frac{l_r - 2\cdot a_\theta}{2}\right)\cdot\sin(\theta)\right]\right]\ldots + p_{A2}^{\langle A2\rangle}\cdot\left(l_r\cdot\Delta\right)\cdot\sin(\theta)\cdot\left(\frac{l_r}{2}\cdot\sin(\theta)\right)\right] + \phi\cdot DL_{roof}\cdot W\cdot\Delta\cdot\left(\frac{W}{2} - o\right)\right]$$

$$R_1 = \begin{pmatrix}-1401.71\\-797.94\end{pmatrix}\text{lbf}$$

$$p_{A2}^{\langle A2E\rangle} = \begin{pmatrix}-39.56\\-28.16\end{pmatrix}\text{psf}$$

$$p_{A2}^{\langle A2\rangle} = \begin{pmatrix}-27.53\\-16.14\end{pmatrix}\text{psf}$$

$$R_2 := p_{A2}^{\langle A2E\rangle}\cdot 2\cdot a_\theta\cdot\Delta\cdot\cos(\theta) + p_{A2}^{\langle A2\rangle}\cdot\left(2\cdot l_r - 2\cdot a_\theta\right)\cdot\Delta\cdot\cos(\theta)\ldots + -R_1 + \phi\cdot DL_{roof}\cdot\Delta\cdot W$$

$$R_2 = \begin{pmatrix}-1199.05\\-595.27\end{pmatrix}\text{lbf}$$

$R_T := \text{stack}(R_1, R_2)$ $\qquad R_{MWF_2} := \min((R_T))$ $\qquad R_{MWF_2} = -1401.71\ \text{lbf}$

CASE B Corner 2

Assume truss is on windward side of imaginary ridge line. All wind zones are Zone 2 or 2E.

$$R_1 := \frac{1}{W - 2\cdot o}\cdot\left[\left[\left[p_{B2}^{\langle B2E\rangle}\cdot 2\cdot a_\theta\cdot\Delta\cos(\theta)\cdot(W - o - a_\theta\cdot\cos(\theta))\right] \ldots + \left[p_{B2}^{\langle B2\rangle}\cdot(l_r - 2\cdot a_\theta)\cdot\Delta\cos(\theta)\cdot\left[W - o - 2\cdot a_\theta\cdot\cos(\theta) - \frac{(l_r - 2\cdot a_\theta)}{2}\cdot\cos(\theta)\right]\right] \ldots + p_{B2}^{\langle B2\rangle}\cdot l_r\cdot\Delta\cos(\theta)\cdot\left(\frac{l_r}{2}\cdot\cos(\theta) - o\right)\right] \ldots + \left[\left[-p_{B2}^{\langle B2E\rangle}\cdot 2\cdot a_\theta\cdot\Delta\cdot\sin(\theta)\cdot(a_\theta\cdot\sin(\theta))\right] \ldots + \left[-p_{B2}^{\langle B2\rangle}\cdot(l_r - 2\cdot a_\theta)\cdot\Delta\cdot\sin(\theta)\cdot\left[\left(2\cdot a_\theta + \frac{l_r - 2\cdot a_\theta}{2}\right)\cdot\sin(\theta)\right]\right] \ldots + p_{B2}^{\langle B2\rangle}\cdot l_r\cdot\Delta\cdot\sin(\theta)\cdot\left(\frac{l_r}{2}\cdot\sin(\theta)\right)\right] + \phi\cdot DL_{roof}\cdot W\cdot\Delta\cdot\left(\frac{W}{2} - o\right)\right]$$

$$p_{B2}^{\langle B2E\rangle} = \begin{pmatrix} -39.56 \\ -28.16 \end{pmatrix} psf$$

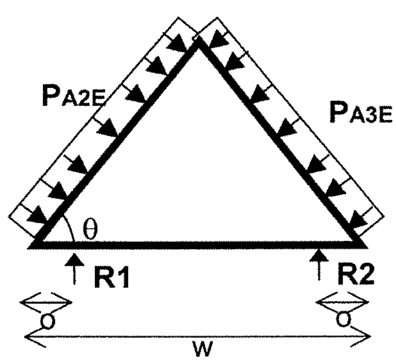
$$R_1 = \begin{pmatrix} -1401.71 \\ -797.94 \end{pmatrix} lbf$$

$$p_{B2}^{\langle B2\rangle} = \begin{pmatrix} -27.53 \\ -16.14 \end{pmatrix} psf$$

$$R_2 := p_{B2}^{\langle B2E\rangle}\cdot 2\cdot a_\theta\cdot\Delta\cdot\cos(\theta) + p_{B2}^{\langle B2\rangle}\cdot(2\cdot l_r - 2\cdot a_\theta)\cdot\Delta\cdot\cos(\theta) \ldots + -R_1 + \phi\cdot DL_{roof}\cdot\Delta\cdot W$$

$$R_2 = \begin{pmatrix} -1199.05 \\ -595.27 \end{pmatrix} lbf \qquad R_T := \text{stack}(R_1, R_2) \qquad R_{MWF_3} := \min((R_T)) \qquad R_{MWF_3} = -1401.71\,lbf$$

Corner Straps - Method 1: Calculate uplift on corner truss by end zone pressure from MWFRS loads



Apply edge zone loads on trib area between end truss and next truss.

$l_r = 29.63\,ft$ $\qquad DL_{roof} = 9\,psf$

$2\cdot a = 10.6\,ft$

$\Delta = 2\,ft$ $\qquad o_g = 1.5\,ft$

CASE A: Corner 1

$$R_1 := \frac{1}{W-2\cdot o}\cdot\left[\begin{array}{l}\left[\begin{array}{l}\left[p_{A1}{}^{\langle A2E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\cdot\left(W-o-\frac{l_r}{2}\cdot\cos(\theta)\right)\ldots\\ +\left[p_{A1}{}^{\langle A3E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\cdot\left(\frac{l_r}{2}\cdot\cos(\theta)-o\right)\ldots\\ +\left[\left[-p_{A1}{}^{\langle A2E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\sin(\theta)\cdot\left(\frac{l_r}{2}\cdot\sin(\theta)\right)\right]\ldots\\ +\left[p_{A1}{}^{\langle A3E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\sin(\theta)\cdot\left(\frac{l_r}{2}\cdot\sin(\theta)\right)\end{array}\right]\ldots\\ +\phi\cdot DL_{roof}\cdot W\cdot\left(\frac{\Delta}{2}+o_g\right)\cdot\left(\frac{W}{2}-o\right)\end{array}\right]$$

$$p_{A1}{}^{\langle A2E\rangle} = \begin{pmatrix}-11.72\\-0.33\end{pmatrix}psf \qquad p_{A1}{}^{\langle A3E\rangle} = \begin{pmatrix}-24.21\\-12.81\end{pmatrix}psf$$

$$R_1 = \begin{pmatrix}-667.78\\86.93\end{pmatrix}lbf$$

$$R_2 := \left[\left[p_{A1}{}^{\langle A2E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\right]\ldots + \left[\left[p_{A1}{}^{\langle A3E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\right] - R_1 + \phi\cdot DL_{roof}\cdot\left(\frac{\Delta}{2}+o_g\right)\cdot W$$

$$R_2 = \begin{pmatrix}-996.68\\-241.96\end{pmatrix}lbf$$

$$R_T := \text{stack}(R_1, R_2) \qquad R_{MWFc_0} := \min((R_T)) \qquad R_{MWFc_0} = -996.68\,lbf$$

CASE B: Corner 1

$$R_1 := \frac{1}{W-2\cdot o}\cdot\left[\begin{array}{l}\left[\begin{array}{l}\left[p_{B1}{}^{\langle B2E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\cdot\left(W-o-\frac{l_r}{2}\cdot\cos(\theta)\right)\ldots\\ +\left[p_{B1}{}^{\langle B3E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\cdot\left(\frac{l_r}{2}\cdot\cos(\theta)-o\right)\ldots\\ +\left[\left[-p_{B1}{}^{\langle B2E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\sin(\theta)\cdot\left(\frac{l_r}{2}\cdot\sin(\theta)\right)\right]\ldots\\ +\left[p_{B1}{}^{\langle B3E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\sin(\theta)\cdot\left(\frac{l_r}{2}\cdot\sin(\theta)\right)\end{array}\right]\ldots\\ +\phi\cdot DL_{roof}\cdot W\cdot\left(\frac{\Delta}{2}+o_g\right)\cdot\left(\frac{W}{2}-o\right)\end{array}\right]$$

$$p_{B1}{}^{\langle B2E\rangle} = \begin{pmatrix}-39.56\\-28.16\end{pmatrix}p \qquad p_{B1}{}^{\langle B3E\rangle} = \begin{pmatrix}-22.47\\-11.08\end{pmatrix}p$$

$$R_1 = \begin{pmatrix}-1921.75\\-1167.04\end{pmatrix}lbf$$

$$R_2 := \left[\begin{array}{l}\left[p_{B1}{}^{\langle B2E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\ldots\\ +\left[p_{B1}{}^{\langle B3E\rangle}\cdot l_r\cdot\left(\frac{\Delta}{2}+o_g\right)\right]\cdot\cos(\theta)\end{array}\right] - R_1 + \phi\cdot DL_{roof}\cdot\left(\frac{\Delta}{2}+o_g\right)\cdot W$$

$$R_2 = \begin{pmatrix}-1471.75\\-717.04\end{pmatrix}lbf$$

$$R_T := \text{stack}(R_1, R_2) \qquad R_{MWFc_1} := \min((R_T)) \qquad R_{MWFc_1} = -1921.75\,lbf$$

CASE A and B for Corner 2

will not govern end truss uplift by inspection.

Summary of Strap Design

Strap Design of interior zone truss:

Components and Cladding: Interior Truss

$$R = \begin{pmatrix} 0 \\ -1724.85 \\ -1451.33 \\ -1357.4 \\ -1357.4 \end{pmatrix} \text{lbf}$$

MWFRS loads: interior zone on single truss (4 values are max uplift from corner 1 Case A & B, corner 2, Case A&B)

$$R_{MWF} = \begin{pmatrix} -626.65 \\ -1011.24 \\ -1401.71 \\ -1401.71 \end{pmatrix} \text{lbf}$$

$\min(R) = -1724.85 \text{ lbf}$

$\min(R_{MWF}) = -1401.71 \text{ lbf}$

Behavior of whole roof is governed by sum of all strap resistances - i.e. overall moment of loads, and therefore the modeled value is representative of the bulk of the straps used in house. Therefore, base "design" on interior truss loads from MWFRS according to typical industry practice.

$R_{design} := \min(R_{MWF})$

$R_{design} = -1401.71 \text{ lbf}$

Corner Truss Design: MWFRS

$$R_{MWFc} = \begin{pmatrix} -996.68 \\ -1921.75 \end{pmatrix} \text{lbf}$$

$\min(R_{MWFc}) = -1921.75 \text{ lbf}$

$$\frac{\min(R_{MWFc})}{\min(R_{MWF})} = 1.37$$

Corner strap must be larger by 37 percent, assuming same tributary area. Note that larger tributary areas for girder trusses will require even larger strap sizes.

Shear on Roof-Wall Connectors

Lateral shear loads on connectors rarely govern design and are assumed to be adequate.

WALL DESIGN for Wood Frame Walls

Nominal Wall Design Parameters

Exterior Surface: 7/16" OSB $t_{OSB} := \frac{7}{16} \cdot in$

Interior Surface: 1/2" Gypsum

Nail Size: 8d common

$\Delta_{stud} := \begin{pmatrix} 12 \\ 16 \end{pmatrix} in$ Spacing of studs in wall, 2 options considered

1. Wall Sheathing Attachment - Suction Loads for Zone 5 C&C loads

Loads:

$Area := 32 \cdot ft^2$ Cladding loads $A_{eff} := 10 \cdot ft^2$ Effective Area for one fastener

$p_{wall} := q_h \cdot \left(GC_p(A_{eff}, 5) + GC_{pi}\right)$ $p_{wall_0} = -50\,psf$

$L_{total} := \left(-p_{wall}\right)_0 \cdot Area$ $L_{total} = 1599.93\,lbf$ suction

Resistance of nails in panel:

$q_r := 41 \cdot \frac{lbf}{in}$ 8d common nail in Southern Pine (SG = 0.55)

$l_{nail} := 2.5in$ length of nail, 8d

$l_p := l_{nail} - t_{OSB}$ $l_p = 2.06\,in$ penetration length

$C_D := 1.6$ Duration factor for short term loads - wind = 10 minutes

$C_m := 1.0$ Condition Factor = assume that wood moisture content at time of construction is same as long term value

$R_{nail} := q_r \cdot l_p \cdot C_D \cdot C_m$ $R_{nail} = 135.3\,lbf$ per nail

$$Nnails_{wall} := 2 \cdot \left[\frac{(8 \cdot ft)}{12 \cdot in} + 1\right] + \left(\frac{4 \cdot ft}{\Delta_{stud}} - 1\right) \cdot \left(\frac{8 \cdot ft}{6 \cdot in} + 1\right) + \left[\frac{4 \cdot ft}{6 \cdot in} - \left(\frac{4 \cdot ft}{\Delta_{stud}} - 1\right)\right] \cdot 2$$

Internal Nails at 12" Edge nails at 6" Top/Bottom Plate at 6"

$Nnails_{wall} = \begin{pmatrix} 79 \\ 64 \end{pmatrix}$

$R_{total} := Nnails_{wall} \cdot R_{nail}$ $R_{total} = \begin{pmatrix} 10688.7 \\ 8659.2 \end{pmatrix} lbf$

$$Status_{WallSuction} := \begin{cases} PASS & \text{if } \left(\min(R_{total}) > L_{total}\right) \\ FAIL & \text{otherwise} \end{cases}$$

$Status_{WallSuction} = 1$

Resistance of Wall (Wood): Consider three stud sizes - 2x4, 2x6 and 2x8's

$$Stud_w := \begin{pmatrix} 1.5\cdot in \\ 1.5\cdot in \\ 1.5\cdot in \end{pmatrix} \quad Stud_d := \begin{pmatrix} 3.5\cdot in \\ 5.5\cdot in \\ 7.25\cdot in \end{pmatrix}$$

2x4 wall, Dressed dim, Table 1A from NDS97-S
2x6 wall
2x8 wall

$isize := 0..2$

$$Stud_{area} := \overrightarrow{(Stud_w \cdot Stud_d)} \qquad Stud_{area} = \begin{pmatrix} 5.25 \\ 8.25 \\ 10.88 \end{pmatrix} in^2$$

Section modulus: NDS-S97

$$S_{xx} := \begin{pmatrix} 3.063 \\ 7.563 \\ 13.14 \end{pmatrix} \cdot in^3 \qquad S_{yy} := \begin{pmatrix} 1.313 \\ 2.063 \\ 2.719 \end{pmatrix} \cdot in^3$$

Moment of Inertia

$$I_{xx} := \begin{pmatrix} 5.359 \\ 20.80 \\ 47.63 \end{pmatrix} \cdot in^4 \qquad I_{yy} := \begin{pmatrix} 0.984 \\ 1.547 \\ 2.039 \end{pmatrix} \cdot in^4$$

<u>Design Values from Table 4B, NDS-S 1997</u>

$F_b := 1500 \cdot psi$ Bending stress, allowable

$F_t := 825 \cdot psi$ Tension Parallel to grain, allowable

$F_v := 90 \cdot psi$ Shear parallel to grain, allowable

$Fcp := 565 \cdot psi$ Compression Perpendicular to grain

$F_c := 1650 \cdot psi$ Compression Parallel to grain

$E := 1600000 \cdot psi$ Modulus of Elasticity

Species and Grade:
Southern Pine, No 2.

Note that selection of species and grade can substantially affect strength of wall. This grade has been confirmed as being readily available in at least Dade county.

2. Wall Bending & Axial Loads

$sp := 0..1$ spacing of studs option variable

Wind Load:

$$A_{eff_{sp}} := \left(\begin{pmatrix} h_{wall}\cdot\Delta_{stud_{sp}} \\ \dfrac{h_{wall}^{2}}{3} \end{pmatrix}\right)$$

For Stud Spacing: $\Delta_{stud_0} = 12\,in$ $\quad A_{eff_0} = \begin{pmatrix} 9.33 \\ 29.04 \end{pmatrix} ft^2$ $\quad A_{eff_0} := \max(A_{eff_0})$ $\quad A_{eff_0} = 29.04\,ft^2$

For Stud Spacing: $\Delta_{stud_1} = 16\,in$ $\quad A_{eff_1} = \begin{pmatrix} 12.44 \\ 29.04 \end{pmatrix} ft^2$ $\quad A_{eff_1} := \max(A_{eff_1})$ $\quad A_{eff_1} = 29.04\,ft^2$

The one third span run tends to govern for all stud spacings, therefore limit effective area to just one area.

$A_{eff} := \max(A_{eff})$ $\qquad A_{eff} = 29.04\,ft^2$

Zone 4

$p_{wall} := q_h\cdot\left(GC_p(A_{eff},4) + GC_{pi}\right)$ $\qquad GC_p(Area,4) + GC_{pi} = \begin{pmatrix} -1.19 \\ 1.09 \end{pmatrix}$ $\qquad p_{wall} = \begin{pmatrix} -37.92 \\ 34.75 \end{pmatrix} psf$

$\omega_{sp} := p_{wall_0}\cdot\Delta_{stud_{sp}}$ $\qquad \omega = \begin{pmatrix} -37.92 \\ -50.56 \end{pmatrix} \dfrac{1}{ft}\,lbf$ $\qquad M_{sp} := \dfrac{\omega_{sp}\cdot h_{wall}^{2}}{8}$ $\qquad M = \begin{pmatrix} -412.88 \\ -550.51 \end{pmatrix} ft\,lbf$

Axial Load:

$DL_{roof} = 9\,psf$ $\qquad L = 63\,ft$ $\qquad W = 53\,ft$

$Load_{stud} := \dfrac{(DL_{roof}\cdot W\cdot L)}{2\cdot L}\cdot\Delta_{stud}$ $\qquad Load_{stud} = \begin{pmatrix} 238.5 \\ 318 \end{pmatrix} lbf$

assume all load carried by long walls

Lumber Property Adjustments

$C_{Dwind} := 1.6$ $\quad C_L := 1.0$ Continuous Lateral Bracing (from sheathing)

$C_{Dgravity} := 1.25$

$$C_r := \begin{pmatrix} 1.5 \\ 1.4 \\ 1.3 \end{pmatrix}$$

Repetitive Loading Factor, from Table 2313.3 FBC pg 23.23 assuming 3/8 sheathing with gypsum board, and 8d nails at 6"/12" spacing

$$C_F := \begin{pmatrix} 1.0 & 1.0 & 1.0 \\ 1.0 & 1.0 & 1.0 \\ 1.0 & 1.0 & 1.0 \end{pmatrix}$$

for compression
for tension
for bending

Size Factor, Not applicable to Southern Pine

2 x4, x6, x8

Calculate Adjusted Bending Capacity

$$Fb\_a_{isize} := Fb \cdot C_{Dwind} \cdot C_L \cdot \left(C_F^{\langle isize \rangle}\right)_2 \cdot Cr_{isize} \qquad Fb\_a = \begin{pmatrix} 3600 \\ 3360 \\ 3120 \end{pmatrix} \text{psi} \qquad \left(C_F^{\langle 0 \rangle}\right)_2 = 1$$

Calculate adjusted compressive Capacity

$$Fc\_star_{isize} := F_c \cdot C_{Dwind} \cdot \left(C_F^{\langle isize \rangle}\right)_0 \qquad Fc\_star = \begin{pmatrix} 2640 \\ 2640 \\ 2640 \end{pmatrix} \text{psi}$$

Euler Buckling Load

$K_{cE} := 0.3$ visually graded lumber

$c := 0.8$ sawn lumber

$K_l := 1.0$ Effective length factor (Assume pin-pin column)

$$F_{cE} := \frac{K_{cE} \cdot E}{\left[\left(\frac{K_l \cdot h_{wall}}{Stud_d}\right)^2\right]} \qquad F_{cE} = \begin{pmatrix} 468.75 \\ 1157.53 \\ 2011.32 \end{pmatrix} \text{psi}$$

Euler buckling pressure

$$C_{p\_col} := \overrightarrow{\left[\frac{1 + \frac{F_{cE}}{F_{c\_star}}}{2 \cdot c} - \sqrt{\left(\frac{1 + \frac{F_{cE}}{F_{c\_star}}}{2 \cdot c}\right)^2 - \frac{\frac{F_{cE}}{F_{c\_star}}}{c}}\right]} \qquad C_{p\_col} = \begin{pmatrix} 0.17 \\ 0.39 \\ 0.59 \end{pmatrix}$$

Column stability factor

$$F_{c\_a_{isize}} := F_c \cdot C_{Dwind} \cdot \left(C_F^{\langle isize \rangle}\right)_0 \cdot C_{p\_col_{isize}} \qquad F_{c\_a} = \begin{pmatrix} 450.24 \\ 1026.81 \\ 1560.33 \end{pmatrix} \text{psi}$$

Combined Bending and Axial Compression Capacity for Wind and Gravity (Dead Load) using combined stress interaction equation NDS 3.9.2 (also see p3.27 of Wood Engineering and Construction Handbook)

For Stud Spacing of: $sp := 1$ $\Delta_{stud_{sp}} = 16\,in$

Bending stress for: $f_b := \frac{(-M_{sp})}{S_{xx}}$ $f_b = \begin{pmatrix} 2156.75 \\ 873.48 \\ 502.75 \end{pmatrix} psi$

compressive stress $f_c := \frac{Load_{stud_{sp}}}{Stud_{area}}$ $f_c = \begin{pmatrix} 60.57 \\ 38.55 \\ 29.24 \end{pmatrix} psi$

Allowable values: $F_{c\_a} = \begin{pmatrix} 450.24 \\ 1026.81 \\ 1560.33 \end{pmatrix} psi$ $F_{b\_a} = \begin{pmatrix} 3600 \\ 3360 \\ 3120 \end{pmatrix} psi$

Interaction Equation:

$$axial_{isize} := \left(\frac{f_{c_{isize}}}{F_{c\_a_{isize}}}\right)^2 \qquad bend_{isize} := \frac{f_{b_{isize}}}{F_{b\_a_{isize}} \cdot \left(1 - \frac{f_{c_{isize}}}{F_{cE_{isize}}}\right)} \qquad \left(1 - \frac{f_{c_{isize}}}{F_{cE_{isize}}}\right) =$$

0.87
0.97
0.99

$$axial = \begin{pmatrix} 0.018 \\ 0.001 \\ 0 \end{pmatrix} \qquad bend = \begin{pmatrix} 0.69 \\ 0.27 \\ 0.16 \end{pmatrix}$$

$$CSIequation_{isize} := axial_{isize} + bend_{isize} \qquad CSIequation = \begin{pmatrix} 0.71 \\ 0.27 \\ 0.16 \end{pmatrix}$$

$Status_{Wood\_Bending2x4} :=$ | PASS if $(CSIequation_0) \le 1.0$ / FAIL otherwise $\qquad Status_{Wood\_Bending2x4} = 1$

$Status_{Wood\_Bending2x6} :=$ | PASS if $(CSIequation_1) \le 1.0$ / FAIL otherwise $\qquad Status_{Wood\_Bending2x6} = 1$

$Status_{Wood\_Bending2x8} :=$ | PASS if $(CSIequation_2) \le 1.0$ / FAIL otherwise $\qquad Status_{Wood\_Bending2x8} = 1$

$$Spacing2x4 := if\left(Status_{Wood\_Bending2x4} = PASS, \Delta_{stud_{sp}}, 0\right)$$

$sp := 0$ Repeat Bending Calculations for spacing of $\Delta_{stud_{sp}} = 12\,in$

Bending stress for: $f_b := \frac{(-M_{sp})}{S_{xx}}$ $f_b = \begin{pmatrix} 1617.56 \\ 655.11 \\ 377.06 \end{pmatrix} psi$

compressive stress $f_c := \frac{Load_{stud_{sp}}}{Stud_{area}}$ $f_c = \begin{pmatrix} 45.43 \\ 28.91 \\ 21.93 \end{pmatrix} psi$

Interaction Equation:

$$axial_{isize} := \left(\frac{f_{c_{isize}}}{F_{c\_a_{isize}}}\right)^2 \qquad bend_{isize} := \frac{f_{b_{isize}}}{F_{b\_a_{isize}} \cdot \left(1 - \frac{f_{c_{isize}}}{F_{cE_{isize}}}\right)} \qquad \left(1 - \frac{f_{c_{isize}}}{F_{cE_{isize}}}\right) = \begin{pmatrix} 0.9 \\ 0.98 \\ 0.99 \end{pmatrix}$$

$$axial = \begin{pmatrix} 0.01 \\ 0.001 \\ 0 \end{pmatrix} \qquad bend = \begin{pmatrix} 0.5 \\ 0.2 \\ 0.12 \end{pmatrix}$$

$$CSIequation_{isize} := axial_{isize} + bend_{isize} \qquad CSIequation = \begin{pmatrix} 0.51 \\ 0.2 \\ 0.12 \end{pmatrix}$$

$Status_{Wood\_Bending2x4} :=$ | PASS if $(CSIequation_0) \le 1.0$ | FAIL otherwise — $Status_{Wood\_Bending2x4} = 1$

$Status_{Wood\_Bending2x6} :=$ | PASS if $(CSIequation_1) \le 1.0$ | FAIL otherwise — $Status_{Wood\_Bending2x6} = 1$

$Status_{Wood\_Bending2x8} :=$ | PASS if $(CSIequation_2) \le 1.0$ | FAIL otherwise — $Status_{Wood\_Bending2x8} = 1$

Check if spacing of 2x4's needs to be decreased

$Spacing2x4 := if(Spacing2x4 = 0, if(Status_{Wood\_Bending2x4} = PASS, \Delta_{stud_{sp}}, 0), Spacing2x4)$

$Spacing2x4 = 16\,in$

3. Calculate adjusted axial load only case

$$F_{c\_star_{isize}} := F_c \cdot C_{Dgravity} \cdot \left(C_F^{\langle isize \rangle}\right)_0 \qquad F_{c\_star} = \begin{pmatrix} 2062.5 \\ 2062.5 \\ 2062.5 \end{pmatrix} psi$$

Euler Buckling Load

$K_{cE} := 0.3$ visually graded lumber

$c := 0.8$ sawn lumber

$K_l := 1.0$ Effective length factor (Assume pin-pin column)

$$F_{cE} := \frac{K_{cE} \cdot E}{\left[\left(\frac{K_l \cdot h_{wall}}{Stud_d}\right)^2\right]} \qquad F_{cE} = \begin{pmatrix} 468.75 \\ 1157.53 \\ 2011.32 \end{pmatrix} psi$$

Euler buckling pressure

$$C_{p\_col} := \overrightarrow{\left[\frac{1 + \frac{F_{cE}}{F_{c\_star}}}{2 \cdot c} - \sqrt{\left(\frac{1 + \frac{F_{cE}}{F_{c\_star}}}{2 \cdot c}\right)^2 - \frac{\frac{F_{cE}}{F_{c\_star}}}{c}}\right]} \qquad C_{p\_col} = \begin{pmatrix} 0.22 \\ 0.48 \\ 0.68 \end{pmatrix}$$

Column stability factor

$$F_{c\_a_{isize}} := \left[F_c \cdot C_{Dgravity} \cdot \left(C_F^{\langle isize \rangle}\right)_0 \cdot C_{p\_col_{isize}}\right] \qquad F_{c\_a} = \begin{pmatrix} 444.35 \\ 980.06 \\ 1407.11 \end{pmatrix} psi$$

$$CSIequation := \overrightarrow{\frac{f_c}{F_{c\_a}}} \qquad CSIequation = \begin{pmatrix} 0.1 \\ 0.03 \\ 0.02 \end{pmatrix}$$

$$Status_{Wood\_Axial} := \begin{cases} PASS & \text{if } \max(CSIequation) \le 1.0 \\ FAIL & \text{otherwise} \end{cases} \qquad Status_{Wood\_Axial} = 1$$

4. Bearing Capacity of Top Plate

Not a capacity limit state. OK by inspection

Lateral Shear Design of Wood Walls

1. Wind Loads

Normal to ridge for roof slope higher than 10 degrees: $\frac{L}{W} = 1.19$ $\frac{h}{L} = 0.25$

Look up values from Figure 6-3 (ASCE 7-98)

$C_{p\_wall\_windward} := 0.8$ $C_{p\_wall\_leeward} := -0.5$

Wind Normal to ridge $C_{p\_roof\_windward} := \begin{pmatrix} 0.3 \\ -0.2 \end{pmatrix}$ $C_{p\_roof\_leeward} := -0.6$

Wind Parallel to ridge $C_{p\_roof\_windward\_ll} := \begin{pmatrix} 0.3 \\ -0.9 \end{pmatrix}$ assume windward hip acts similar to wind normal to ridge case

$G = 0.88$ $C_{p\_roof\_leeward\_ll} := -0.3$ from normal to ridge section of Fig 6-3

2. Shear Load per wall: (Roof loads plus half of wall loads)

Note: internal pressures cancel and therefore are ignored in calculating total shear

Wind Perpendicular to Ridge:

MWFRS Roof Pressure $MWFRS_{roof\Gamma} := q_h \cdot \left[\left(G \cdot C_{p\_roof\_windward_0} \right) - \left(G \cdot C_{p\_roof\_leeward} \right) \right]$

MWFRSWall Wall Pressure $MWFRS_{wall\Gamma} := q_h \cdot \left(\left(G \cdot C_{p\_wall\_windward} - G \cdot C_{p\_wall\_leeward} \right) \right)$

$MWFRS_{roof\Gamma} = 25.04\,psf$ $MWFRS_{wall\Gamma} = 36.17\,psf$ $q_h = 31.64\,psf$

Total Shear from Roof $VPA_{\Gamma} \cdot MWFRS_{roof\Gamma} = 12109.83\,lbf$

Total Shear from Wall $VPA_{wall\Gamma} \cdot MWFRS_{wall\Gamma} = 10633.53\,lbf$

Total shear $Shear_{\Gamma} := VPA_{wall\Gamma} \cdot MWFRS_{wall\Gamma} + VPA_{\Gamma} \cdot MWFRS_{roof\Gamma}$ $Shear_{\Gamma} = 22743.4\,lbf$

Wind Parallel to Ridge:

MWFRS Roof Pressure $q_h \cdot \left[\left(G \cdot C_{p\_roof\_windward\_ll_0} \right) - \left(G \cdot C_{p\_roof\_leeward\_ll} \right) \right] = 16.69\,psf$

MWFRSWall Wall Pressure $q_h \cdot \left(\left(G \cdot C_{p\_wall\_windward} - G \cdot C_{p\_wall\_leeward} \right) \right) = 36.17\,psf$

Total Shear from Roof $VPA_{ll} \cdot q_h \cdot \left[\left(G \cdot C_{p\_roof\_windward\_ll_0} \right) - \left(G \cdot C_{p\_roof\_leeward\_ll} \right) \right] = 5861.38\,lbf$

Total Shear from Wall $VPA_{wall\_ll} \cdot q_h \cdot \left(G \cdot C_{p\_wall\_windward} - G \cdot C_{p\_wall\_leeward} \right) = 8945.67\,lbf$

Total shear

$$Shear_{ll} := q_h \cdot \begin{bmatrix} VPA_{ll} \cdot \left[\left(G \cdot C_{p\_roof\_windward\_ll_0} \right) - \left(G \cdot C_{p\_roof\_leeward\_ll} \right) \right] \cdots \\ + VPA_{wall\_ll} \cdot \left[\left(G \cdot C_{p\_wall\_windward} \right) - \left(G \cdot C_{p\_wall\_leeward} \right) \right] \end{bmatrix}$$

$Shear_{ll} = 14807\,lbf$

3. Allowable shear resistance from NDS Supplement for structural use panel shear wall and diaphragm

Wall properties: (see above)

Exterior Surface: 7/16" OSB $t_{OSB} = 0.438\,in$

Interior Surface: 1/2" Gypsum

Blocked construction

Nail Size: 8d common Nail spacing: 6"/12"

$\Delta_{stud} = \begin{pmatrix} 12 \\ 16 \end{pmatrix} in$ Spacing of studs in wall

$Shear_{allowable} := 310 \cdot \frac{lbf}{ft}$

Table 4.1A of Structural Use Panel Shear Wall and Diaphragm Supplement to NDS 1997
3/8" sheathing with 8d nails 6" at edges

$L_{shearMin\_\Gamma} := \frac{Shear_{\Gamma}}{Shear_{allowable}}$ $L_{shearMin\_\Gamma} = 73.37\,ft$

$L_{shearMin\_ll} := \frac{Shear_{ll}}{Shear_{allowable}}$ $L_{shearMin\_ll} = 47.76\,ft$

Actual length available for shear walls:

$L_{shearwall\_Actual\_\Gamma} := (30 \;\; 24 \;\; 18 \;\; 20 \;\; 8)^{T} \cdot ft$ $\sum L_{shearwall\_Actual\_\Gamma} = 100\,ft$

$L_{shearwall\_Actual\_ll} := (4 \;\; 4 \;\; 10 \;\; 4 \;\; 24 \;\; 10 \;\; 4 \;\; 4 \;\; 4 \;\; 4)^{T} \cdot ft$ $\sum L_{shearwall\_Actual\_ll} = 72\,ft$

$$Status_{Wood\_Shear} := \begin{vmatrix} PASS \;\; if \left(\sum L_{shearwall\_Actual\_\Gamma} > L_{shearMin\_\Gamma}\right) \cdot \left(\sum L_{shearwall\_Actual\_ll} > L_{shearMin\_ll}\right) \\ FAIL \;\; otherwise \end{vmatrix}$$

$Status_{Wood\_Shear} = 1$

Wood frame walls must be constructed with full structural sheathing in order to meet shear load requirements.

4. Shear of Anchor Bolts

Anchor bolts 5/8" diameter embedded in concrete 6" trough 2x4 bottom plate.

$Z := 890 \cdot lbf$ — For Specific Gravity wood of 0.5, Table 8.2E of NDS supplement for connections

$C_t := 1.0$ — temperature service factor

$C_{others} := 1.0$ — bunch of other factors for end grain, toenail, etc. which are all 1.0

$C_g := 1.0$ — Group Action Factor: fasteners are several feet apart and therefore behave as single fasteners

$Z\_a := Z \cdot C_{Dwind} \cdot C_m \cdot C_t \cdot C_g \cdot C_{others}$ $\quad Z\_a = 1424\,lbf$ Shear capacity per bolt

$Shear_{\Gamma} = 22743.36\,lbf$ shear to resist total ... (worst case)

$N_{bolts} := \frac{Shear_{\Gamma}}{Z\_a}$ $\quad N_{bolts} = 15.97$

$\Delta_{bolt} := floor\left(\frac{2 \cdot W}{N_{bolts}}\right)$ $\quad \Delta_{bolt} = 6\,ft$ Use one bolt every $\Delta_{bolt} = 6\,ft$

WALL DESIGN for Masonry Walls (ACI 530-99)

1. Choosing Spacing of Vertical Reinforcement in Reinforced Wall

Select Vertical Wall Reinforcement based horizontal flexure between grouted cells - horizontal span

To determining the spacing of the vertical reinforcement, we have used the method cited in "Masonry Structures Behavior and Design" by Drysdale, R. G., Hamid, A. A., and Baker, L. R. In this book it is stated that when the spacing of reinforcement is greater than beff the wall is considered as reinforced strips beff wide with unreinforced strips in between. Therefore, "The reinforced strips are designed to carry the full load and the unreinforced masonry must be capable of spanning a horizontal distance between reinforcement". In addition, ACI 530 specifies a maximum reinforcement only for seismic zones. Therefore, if you are not in a seismic zone you don't have to worr about maximum spacing as long as the unreinforced masonry can carry the load between the grouted cells. Also, a minimum horizontal reinforcement is required by the SFBC (Section 2704.1), which can be used to calculate the spacing of the vertical reinforcement. By not using this vertical reinforcement a conservative estimate of reinforcement spacing is achieved.

Masonry Wall Design Parameters

8" Concrete Block, hollow unit face shell bedding

$b_{CMU} := 15.625 \cdot in \quad d_{CMU} := 7.625 \cdot in$

$h_{CMU} := 7.625 \cdot in$

width of mortar bed on face shell $d_{shell} := 1.25 \cdot in$

Steel Properties

#5 rebar: ASTM A 615

$A_{steel} := 0.31 \cdot in^2$ per bar

$f_y := 60000 \cdot psi$

$f_s := 24000 \cdot psi$

$E_{steel} := 29.5 \cdot 10^6 \cdot psi$

Masonry Properties

$f_b := 30 \cdot psi$ Allowable Flexure Tension of Hollow Unit Concrete Masonry, Ungrouted from Table 2.2.3.2 of ACI 530-99

$f_m := 1500 \cdot psi$ allowable compression stress

$E_m := 900 \cdot f_m$ for fm of 1500 psi masonry

$E_m = 1.35 \times 10^6 \, psi$

Calculate section properties of concrete block in vertical direction: Uncracked section

$A_{yy} := d_{shell} \cdot h_{CMU} \cdot 2$ $\qquad A_{yy} = 19.06 \, in^2$

$$I_{yy} := \frac{h_{CMU}}{12} \cdot \left[d_{CMU}^3 - \left(d_{CMU} - 2 \cdot d_{shell} \right)^3 \right] \qquad I_{yy} = 196.16 \, in^4$$

$$S_{yy} := \frac{h_{CMU} \cdot \left[d_{CMU}^3 - \left(d_{CMU} - 2 \cdot d_{shell} \right)^3 \right]}{6 \cdot d_{CMU}} \qquad S_{yy} = 51.45 \, in^3$$

Limiting moment in wall

$M_{max} := f_b \cdot S_{yy}$ $\qquad$ $M_{max} = 128.63\ \text{ft lbf}$

Wind Load:

$A_{eff} := 8 \cdot 6 \cdot ft^2$ $\qquad$ Zone 5

$p_{wall} := q_h \cdot (GC_p(A_{eff}, 5) + GC_{pi})$ $\qquad$ $GC_p(A_{eff}, 5) + GC_{pi} = \begin{pmatrix} -1.34 \\ 1.06 \end{pmatrix}$ $\qquad$ $p_{wall} = \begin{pmatrix} -42.38 \\ 33.53 \end{pmatrix} psf$

$\omega := p_{wall_0} \cdot h_{CMU}$ $\qquad$ $\omega = -26.93 \frac{1}{ft} lbf$

Maximum spacing of reinforcement

$\Delta_{steel} := \sqrt{\frac{12 \cdot M_{max}}{-\omega}}$ $\qquad$ Assuming fixed-fixed end conditions

$\Delta_{steel} := \text{floor}\left(\frac{\Delta_{steel}}{8 \cdot in}\right) \cdot 8 \cdot in$ $\qquad$ round down to nearest 8" multiple (dist between cells) $\qquad$ $\Delta_{steel} = 88\ in$ $\qquad$ $\Delta_{steel} = 7.33\ ft$

Foundation Design: Sliding and Overturning

$wood \equiv 0$
$masonry \equiv 1$

This section presents a very basic set of calculations to show the difference between a restrained foundation and an unrestrained foundation. The weight of the building, in combination with a coefficient of friction is used to resist the lateral wind loads that create sliding failures as well as overturning failures of the entire building. This section assumes that the soil supporting the foundation can adequately handle any of the lateral wind loads. This analysis is prepared for a wood frame wall connected to a concrete block foundation, if it is adequate, then a masonry building (which weighs more) will also be adequate.

Weight of entire building $wall := wood$

Roof $Weight_0 := DL_{roof} \cdot W \cdot L$ $DL_{roof} = 9\,psf$

Exterior Walls $Weight_1 := DL_{wall_{wall}} \cdot [2 \cdot (L + W)] \cdot h_{wall}$ $DL_{wall_{wall}} = 10\,psf$

Interior Walls $Weight_2 := DL_{wall_{wood}} \cdot (L + W) \cdot h_{wall}$

Misc materials (contents, carpet, drywall) $Weight_3 := DL_{misc} \cdot L \cdot W$ $DL_{misc} = 15\,psf$

$$Weight = \begin{pmatrix} 30051 \\ 21653 \\ 10827 \\ 50085 \end{pmatrix} lbf$$

$$\sum Weight = 112616\,lbf \qquad \frac{\sum Weight}{W \cdot L} = 33.73\,psf$$

Sliding Failures

Assume coefficient of Friction: $\mu := 0.6$ wood on concrete

Shear resistance by friction $ShearR\_gravity := \sum Weight \cdot \mu$

$ShearR\_gravity = 67569.6\ lbf$

Shear resistance of anchor bolts

$Z\_a = 1424\ lbf$ Resistance of single anchor bolt (calulated earlier)

Number of anchor bolts: $N_{bolt} := 2 \cdot \left(floor\left(\frac{L}{\Delta_{bolt}}\right) + 1\right) + 2 \cdot \left(floor\left(\frac{W}{\Delta_{bolt}}\right) + 1 - 2\right)$ $N_{bolt} = 36$

$ShearR\_anchor := Z\_a \cdot N_{bolt}$ $ShearR\_anchor = 51264\ lbf$

Total Resistance to Sliding

$ShearR\_total := ShearR\_gravity + ShearR\_anchor$ $ShearR\_total = 118833.6\ lbf$

Total Shear Load on Building (perpendicular to ridge case considered only -worst case)

$Shear_{\Gamma} = 22743.36\ lbf$ Shear from roof and 1/2 walls

$Shear_{\Gamma\_lowerwall} := VPA_{wall\Gamma} \cdot MWFRS_{wall\Gamma}$ $MWFRS_{wall\Gamma} = 36.17\ psf$

$Shear_{total} := Shear_{\Gamma} + Shear_{\Gamma\_lowerwall}$

$Shear_{total} = 33377\ lbf$

$Status_{Sliding} := \begin{cases} PASS & \text{if } Shear_{total} < ShearR\_total \\ FAIL & \text{otherwise} \end{cases}$ $Status_{Sliding} = 1$

$\frac{ShearR\_total}{Shear_{total}} = 3.56$ Ratio of resistance to loads

Overturning Failures (sum moments about long edge)

Weight of entire building: resisting overturning $\sum \text{Weight} = 112616\,\text{lbf}$

Uplift on Anchor Bolts or rebar

Anchor bolts 5/8" diameter embedded in masonry 6" trough

$l_b := 4 \cdot \text{in}$ Penetration length, assumed at least 4"

$A_p := \pi \cdot l_b^{\,2}$ $A_p = 0.35\,\text{ft}^2$ Equation 2-3 of ACI 530-99

$$B_a := \begin{pmatrix} 0.5 \cdot A_p \cdot \sqrt{\dfrac{f_m}{\text{psi}}} \cdot \text{psi} \\ 0.2 \cdot A_p \cdot f_y \end{pmatrix} \qquad B_a = \begin{pmatrix} 973.39 \\ 603185.79 \end{pmatrix} \text{lbf} \qquad f_y = 60000\,\text{psi} \quad f_m = 1500\,\text{psi}$$

Equation 2-1/2-2 of ACI 530-99

$B_a := \min(B_a)$ $B_a = 973.39\,\text{lbf}$ Allowable force per anchor

Resistance of all anchors along one edge of building

Assume that anchor bolts or rebar spaced according to shear on wood wall requirements calculated earlier

$F_{anchors_0} := B_a \cdot \dfrac{L}{\Delta_{bolt}}$ parallel to ridge

$F_{anchors_1} := B_a \cdot \dfrac{W}{\Delta_{bolt}}$ perpendicular to ridge $F_{anchors} = \begin{pmatrix} 10220.56 \\ 8598.25 \end{pmatrix} \text{lbf}$

Equivalent "resisting" weight added to overturning resistance: sum forces about one edge of building

$$\text{Weight}_{anchors_0} := \left[\frac{F_{anchors_0} \cdot W}{0.5 \cdot W} + 2 \cdot \left(\frac{F_{anchors_1} \cdot W \cdot 0.5}{0.5 \cdot W} \right) \right] \cdot \frac{1}{W \cdot L} \qquad W \cdot L = 3339\,\text{ft}^2$$

$$\text{Weight}_{anchors_1} := \left[\frac{F_{anchors_1} \cdot L}{0.5 \cdot L} + 2 \cdot \left(\frac{F_{anchors_0} \cdot L \cdot 0.5}{0.5 \cdot L} \right) \right] \cdot \frac{1}{W \cdot L} \qquad \text{Weight}_{anchors} = \begin{pmatrix} 11.27 \\ 11.27 \end{pmatrix} \text{psf}$$

Resisting moment

$$\text{Moment}_{resist} := \left(\sum \text{Weight} + \text{Weight}_{anchors_0} \cdot W \cdot L \right) \cdot \frac{W}{2} \qquad \text{Moment}_{resist} = 3.98 \times 10^6\,\text{ft lbf}$$

Wind Loads causing Overturning(for perpendicular to ridge case only - worst case)

vertical loads on roof (uplift) calculate uplift on each half of roof

windward half $MWFRS_{roof\Gamma\_ww} := q_h \cdot \left(G \cdot C_{p\_roof\_windward_0} - GC_{pi_1}\right)$

leeward half $MWFRS_{roof\Gamma\_lw} := q_h \cdot \left(G \cdot C_{p\_roof\_leeward} - GC_{pi_1}\right)$

include internal pressure for uplift (it does not cancel, here)

	moment arm	load	area
lateral loads on roof	$h = 16\,ft$	$MWFRS_{roof\Gamma} = 25.04\,psf$	$VPA_{\Gamma} = 483.62\,ft^2$
lateral loads on wall	$\frac{h_{wall}}{2} = 4.67\,ft$	$MWFRS_{wall\Gamma} = 36.17\,psf$	$2 \cdot VPA_{wall\Gamma} = 588\,ft^2$
vertical loads on roof (uplift)	$W \cdot \frac{3}{4} = 39.75\,ft$	$MWFRS_{roof\Gamma\_ww} = 2.65\,psf$	$\frac{HPA}{2} = 1669.5\,ft^2$
	$W \cdot \frac{1}{4} = 13.25\,ft$	$MWFRS_{roof\Gamma\_lw} = -22.39\,psf$	$\frac{HPA}{2} = 1669.5\,ft^2$

Calculate moments:

lateral loads on roof $Moment_{wind_0} := MWFRS_{roof\Gamma} \cdot VPA_{\Gamma} \cdot h$

lateral loads on wall $Moment_{wind_1} := MWFRS_{wall\Gamma} \cdot 2 \cdot VPA_{wall\Gamma} \cdot \frac{h_{wall}}{2}$

vertical loads on roof (uplift) $Moment_{wind_2} := -MWFRS_{roof\Gamma\_ww} \cdot \frac{HPA}{2} \cdot W \cdot \frac{3}{4}$

$Moment_{wind_3} := -MWFRS_{roof\Gamma\_lw} \cdot \frac{HPA}{2} \cdot \frac{W}{4}$

$$Moment_{wind} = \begin{pmatrix} 193757 \\ 99246 \\ -175901 \\ 495267 \end{pmatrix} ft\,lbf \qquad \sum Moment_{wind} = 6.12 \times 10^5\,ft\,lbf$$

$$Status_{Overturning} := \begin{cases} PASS & \text{if } \sum Moment_{wind} < Moment_{resist} \\ FAIL & \text{otherwise} \end{cases} \qquad Status_{Overturning} = 1$$

$$\frac{Moment_{resist}}{\sum Moment_{wind}} = 6.5$$ Ratio of resistance to loads

Now consider if building was a masonry building, then the Weight of the building would increase, and if we assume the same resistances for sliding and overturning are provided by the rebar in the walls as the anchor bolts in the wood frame case, then resistance to sliding and overturning are just that much larger. In reality resistance to sliding of masonry wall on foundation will be higher than assumed here.

Weight of entire building

$$\text{wall} := \text{masonry}$$

Roof $\quad \text{Weight}_0 := DL_{roof} \cdot W \cdot L \qquad DL_{roof} = 9\,\text{psf}$

Exterior Walls $\quad \text{Weight}_1 := DL_{wall_{wall}} \cdot [2 \cdot (L + W)] \cdot h_{wall} \qquad DL_{wall_{wall}} = 55\,\text{psf}$

Interior Walls $\quad \text{Weight}_2 := DL_{wall_{wood}} \cdot (0.8L + 0.8W) \cdot h_{wall}$

Misc materials (contents, carpet, drywall) $\quad \text{Weight}_3 := DL_{misc} \cdot L \cdot W \qquad DL_{misc} = 15\,\text{psf}$

$$\text{Weight} = \begin{pmatrix} 30051 \\ 119093 \\ 8661 \\ 50085 \end{pmatrix} \text{lbf} \qquad \frac{\sum \text{Weight}}{W \cdot L} = 62.26\,\text{psf}$$

Resistance to Sliding

$$\text{ShearR\_gravity} := \sum \text{Weight} \cdot \mu$$

$$\text{ShearR\_total} := \text{ShearR\_gravity} + \text{ShearR\_anchor}$$

$$\text{ShearR\_total} = 175998.4\,\text{lbf}$$

Loads causing shear

$$\text{Shear}_{total} = 33377\,\text{lbf}$$

Resistance to Overturning

$$\text{Moment}_{resist} := \left(\sum \text{Weight} + \text{Weight}_{anchors_0} \cdot W \cdot L\right) \cdot \frac{W}{2}$$

$$\text{Moment}_{resist} = 6.51 \times 10^6\,\text{ft lbf}$$

Loads causing Overturning

$$\sum \text{Moment}_{wind} = 6.12 \times 10^5\,\text{ft lbf}$$

APPENDIX G:

RCMP DATA PLOTS OF SELECTED VARIABLES

APPENDIX G: RCMP DATA PLOTS OF SELECTED VARIABLES

This appendix contains plots of the following variables:

1. Year Built
2. Insured Building Value
3. Building Class
4. Wall Construction
5. Roof Shape
6. Roof Cover
7. Roof Deck Type
8. Total Roof Deck Thickness
9. Method of Attachment
10. Roof Deck Nail Size
11. Gable End Bracing
12. Rafter/Wall Connection

Each plot is labeled with the region and year of RCMP inspection. The order of the regions is South Florida (pages G-3 through G-8), Panhandle (pages G-9 through G-14), Lee (pages G-15 through G-20), and Tampa (pages G-21 through G-26). The number of records for each region are 1056, 709, 65, and 301, respectively.

These plots do not contain any corrections to the data. In particular, the roof deck nail size data is subject to inspector errors that were discovered through some reinspection work.

Year Built

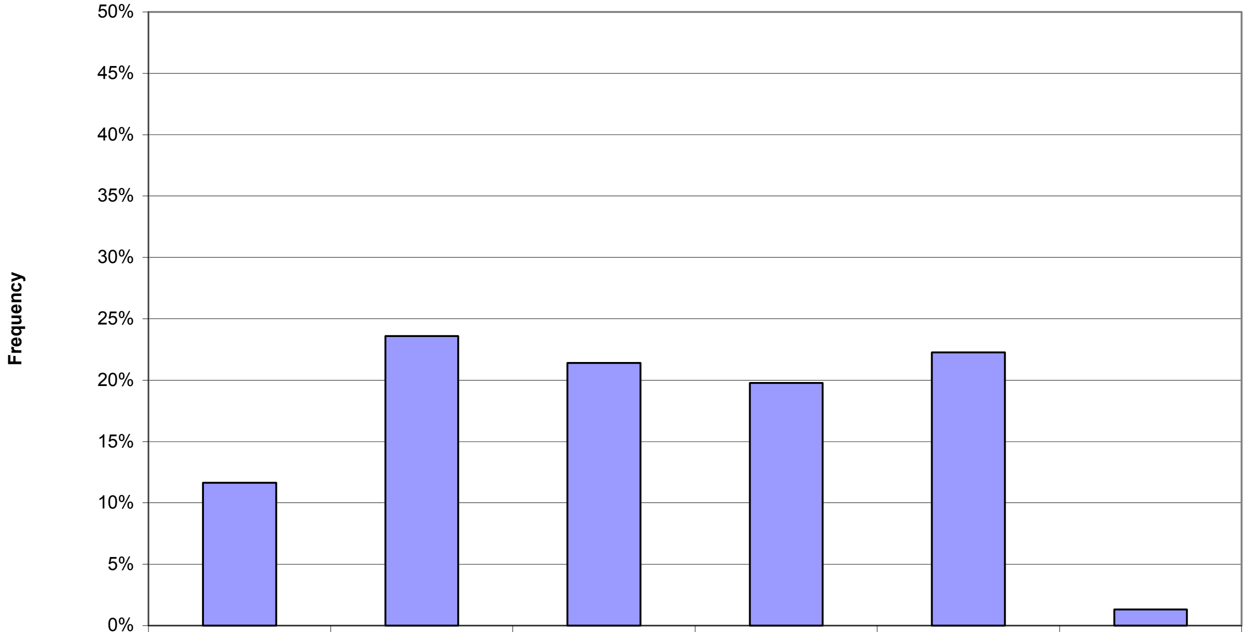
Mean: 1967

Standard Deviation: 14.76

Number of Records: 1056

Data Base: RCMP98

Area: South Florida



	<1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000
Frequency	11.65%	23.58%	21.40%	19.79%	22.25%	1.33%

Year Built

Insured Building Value

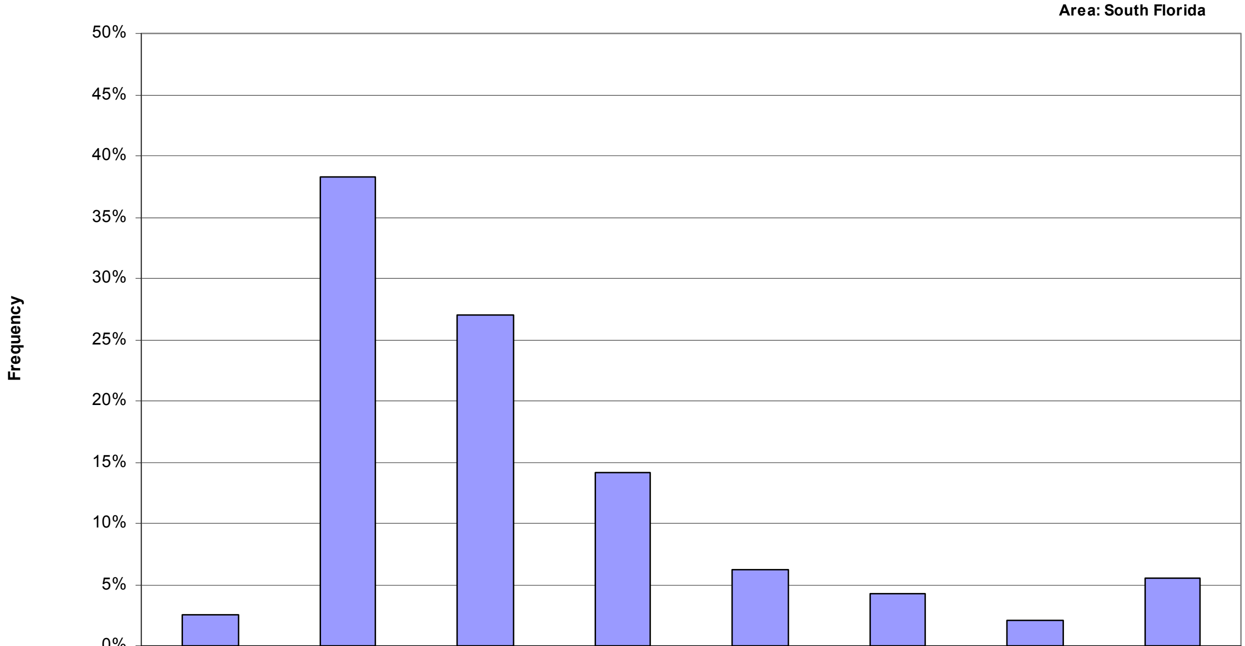
Mean: 151,047

Standard Deviation: 123,396.84

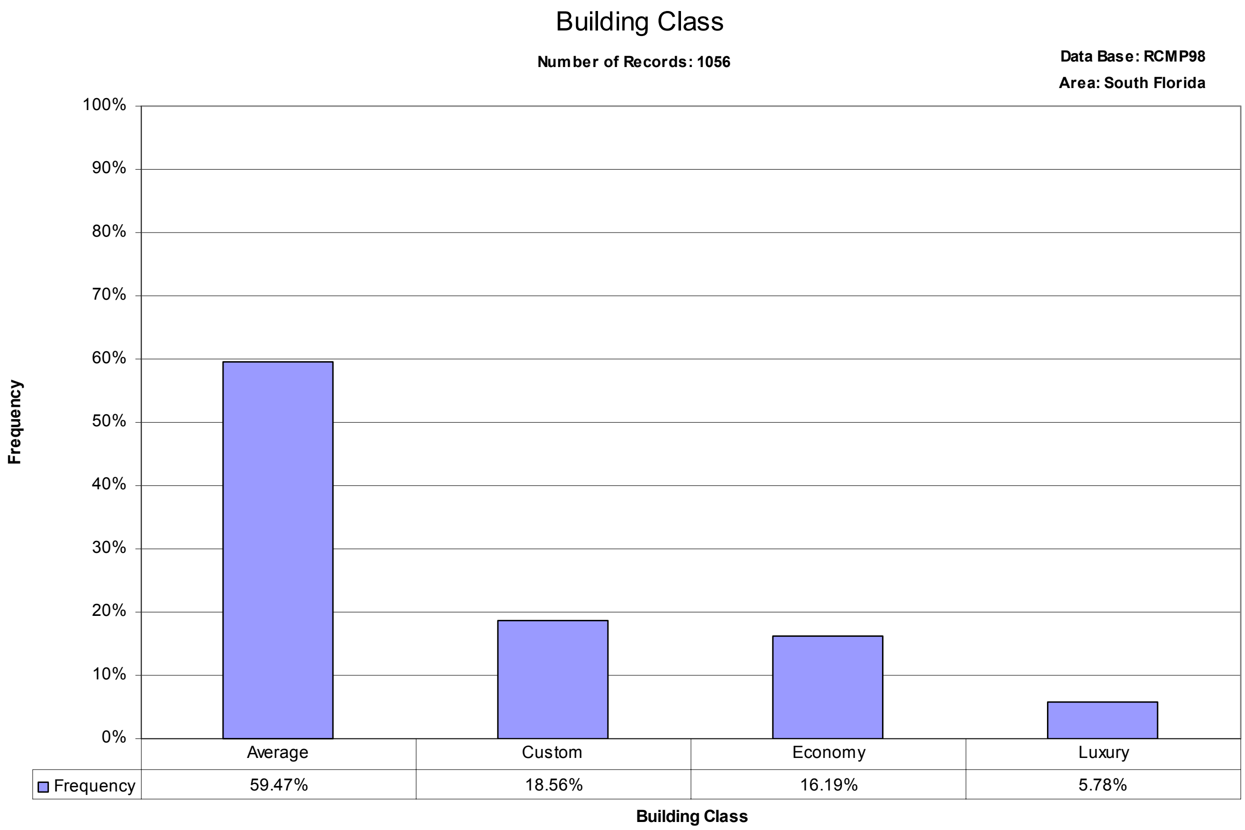
Number of Records: 1056

Data Base: RCMP98

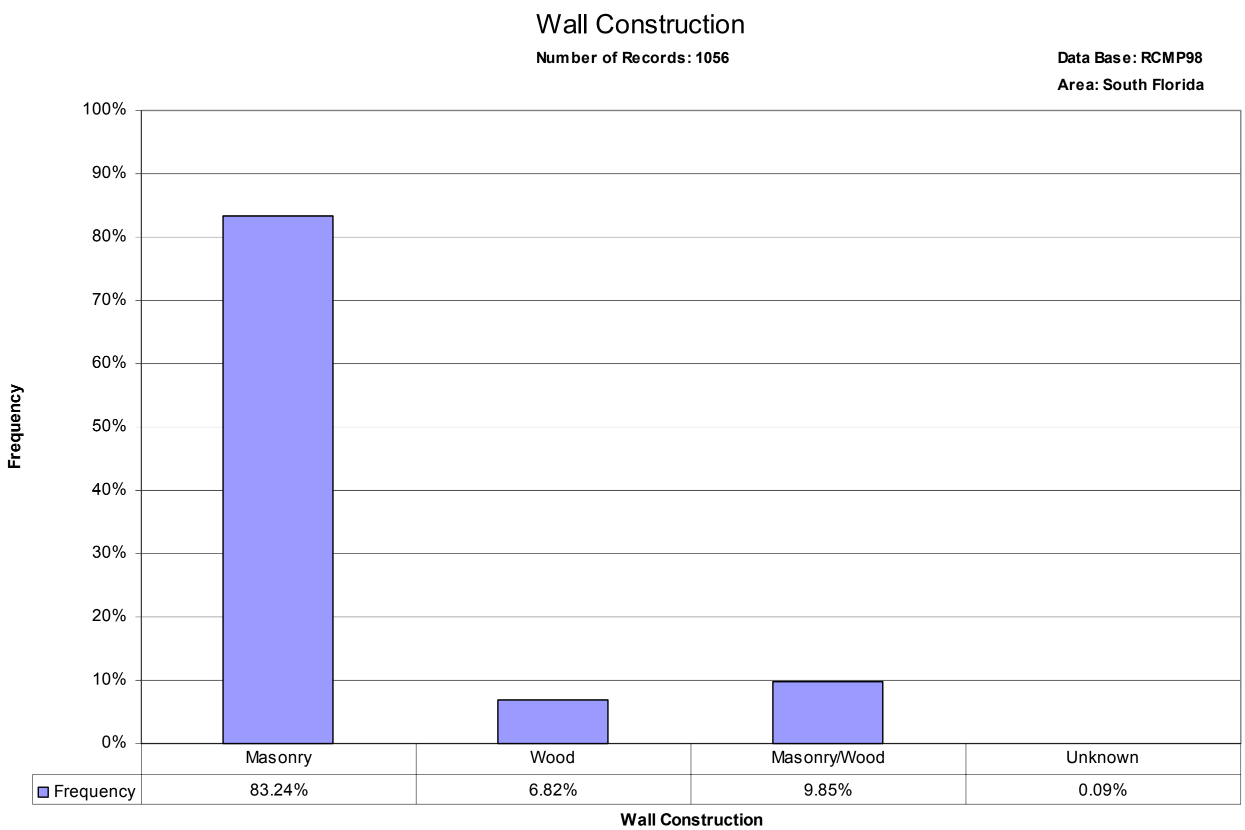
Area: South Florida



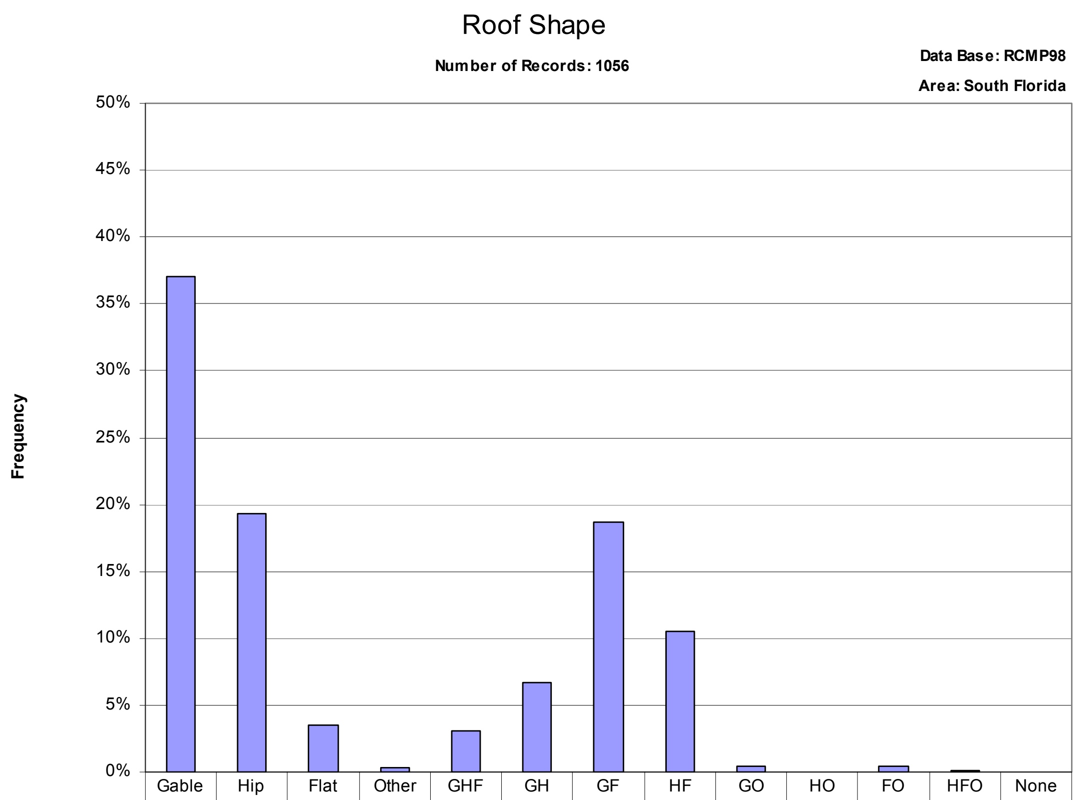
	<50k	50k-100k	100k-150k	150k-200k	200k-250k	250k-300k	300k-350k	350k>
Frequency	2.56%	38.26%	26.99%	14.11%	6.25%	4.26%	2.08%	5.49%



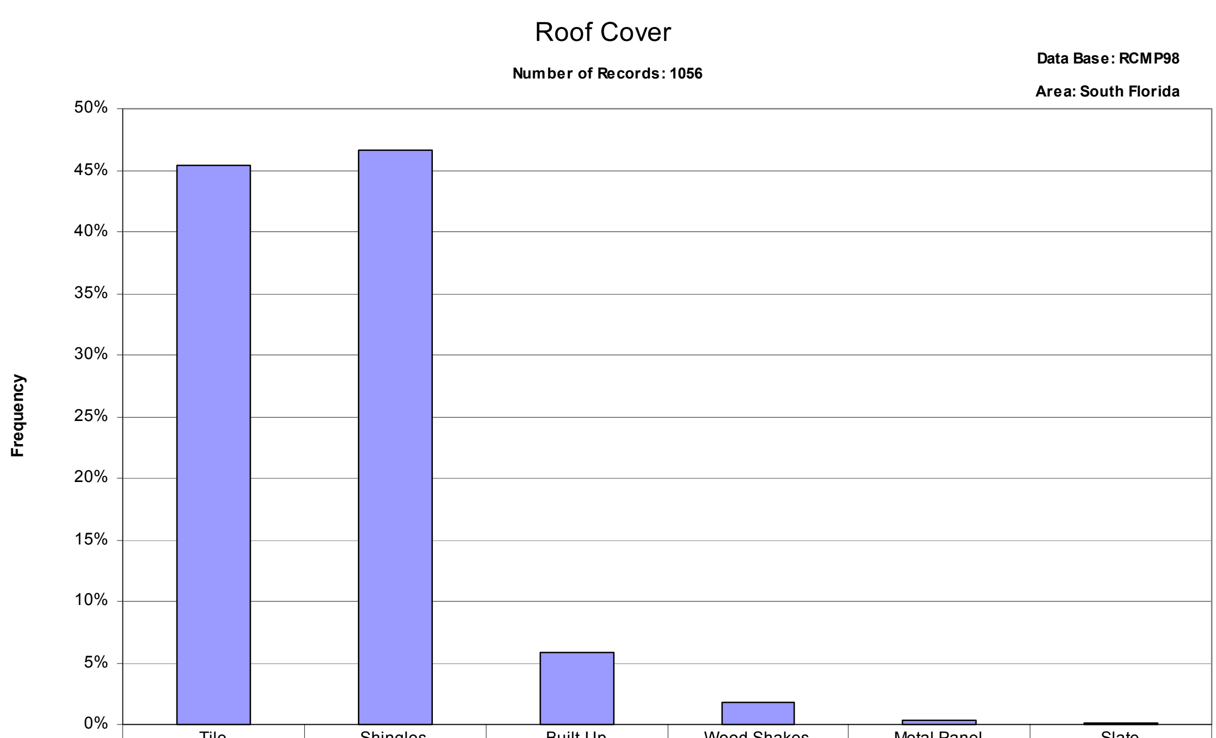
Building Class
Number of Records: 1056
Data Base: RCMP98
Area: South Florida
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Average
Custom
Economy
Luxury
Frequency
59.47%
18.56%
16.19%
5.78%
Building Class



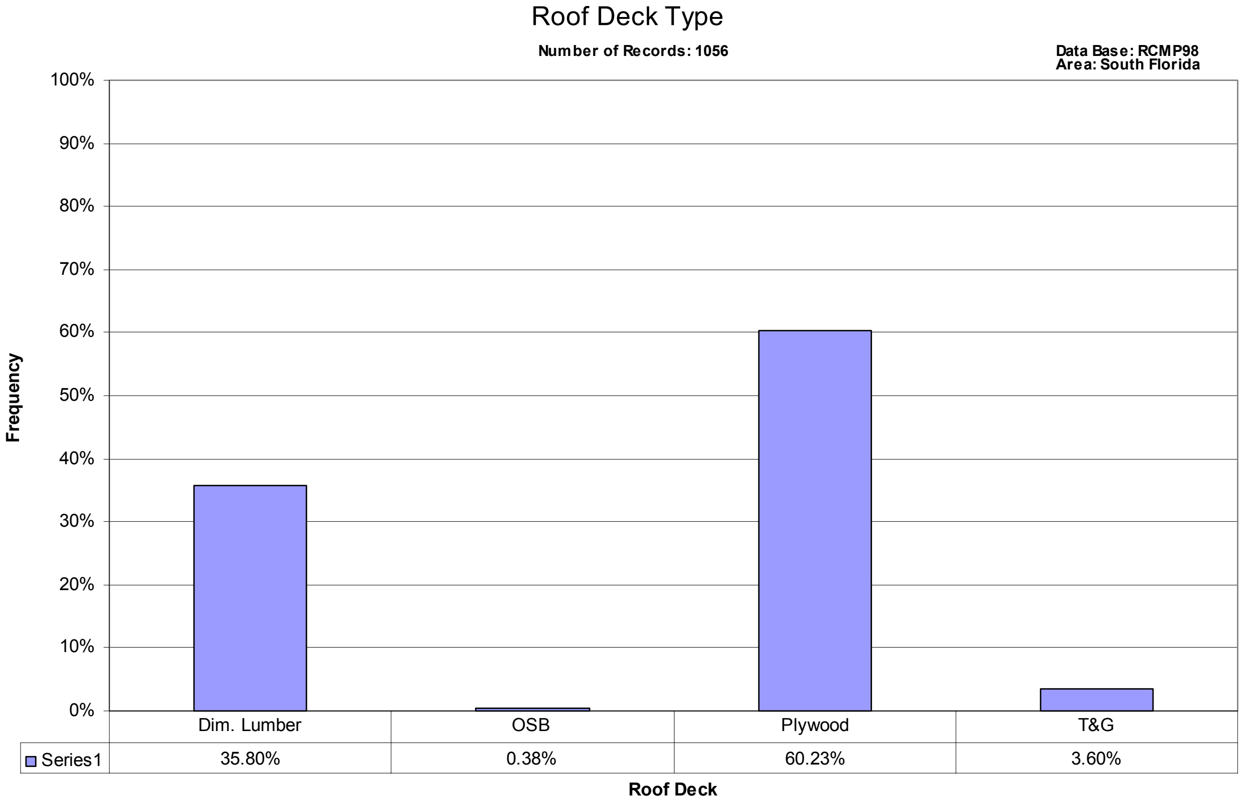
Wall Construction
Number of Records: 1056
Data Base: RCMP98
Area: South Florida
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Masonry
Wood
Masonry/Wood
Unknown
Frequency
83.24%
6.82%
9.85%
0.09%
Wall Construction



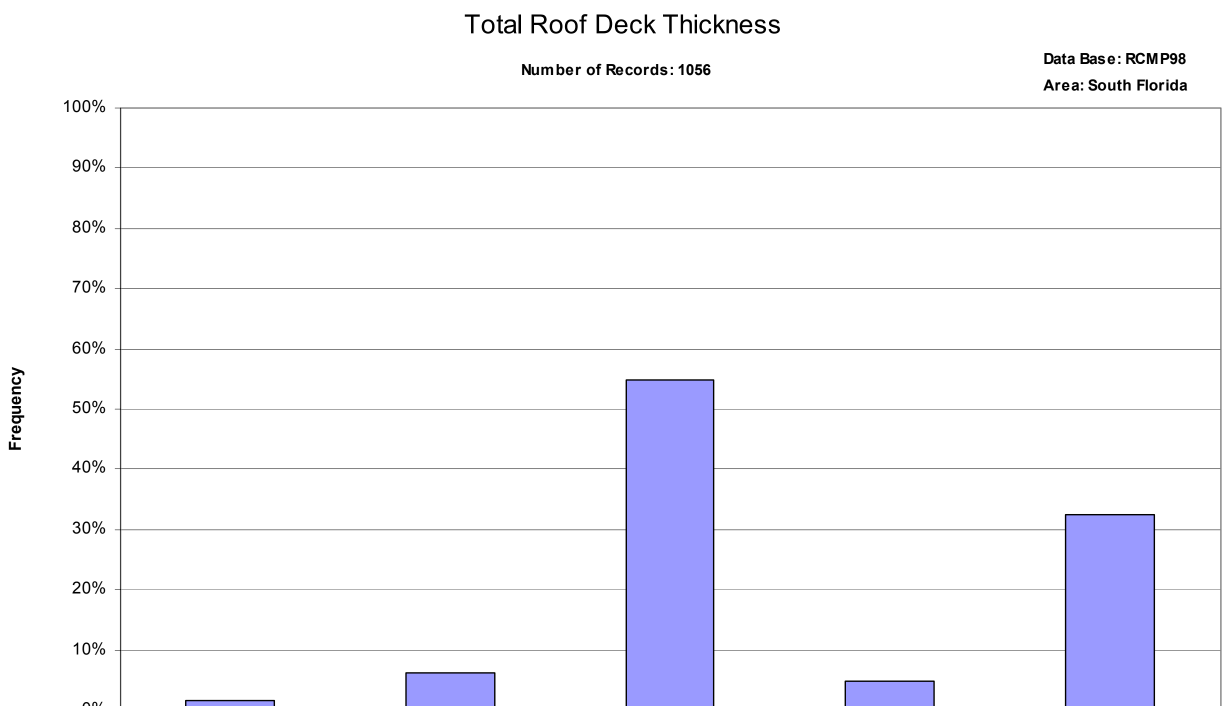
	Gable	Hip	Flat	Other	GHF	GH	GF	HF	GO	HO	FO	HFO	None
Frequency	37.0%	19.3%	3.5%	0.3%	3.1%	6.7%	18.7%	10.5%	0.4%	0.0%	0.4%	0.1%	0.0%



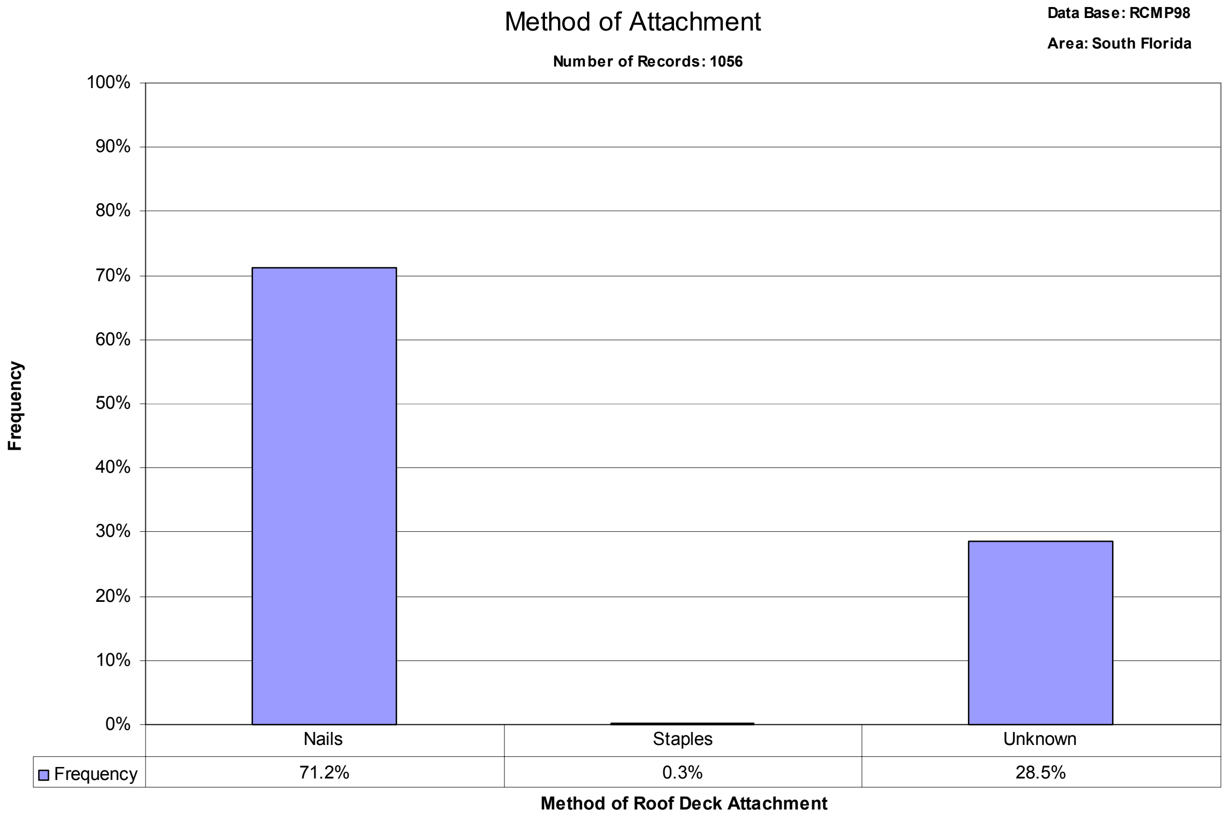
	Tile	Shingles	Built-Up	Wood Shakes	Metal Panel	Slate
Series1	45.36%	46.59%	5.87%	1.80%	0.28%	0.09%

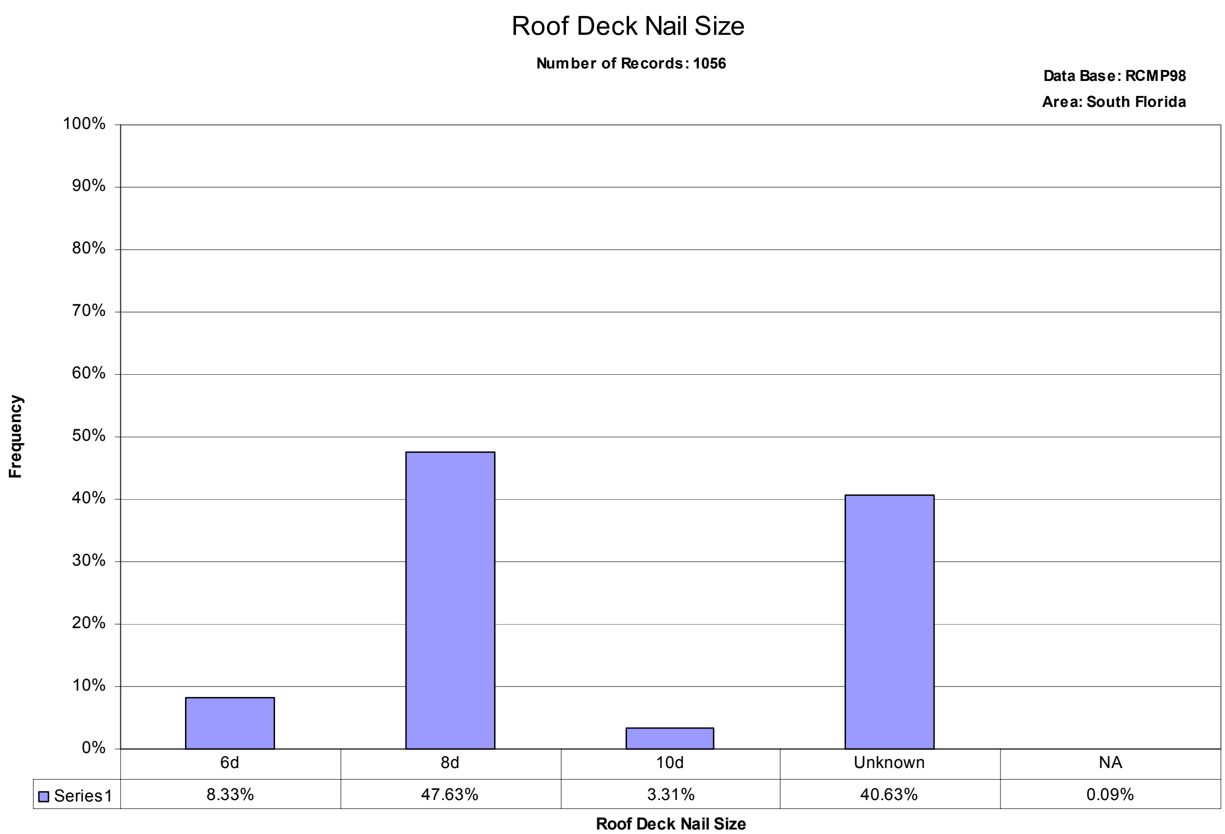


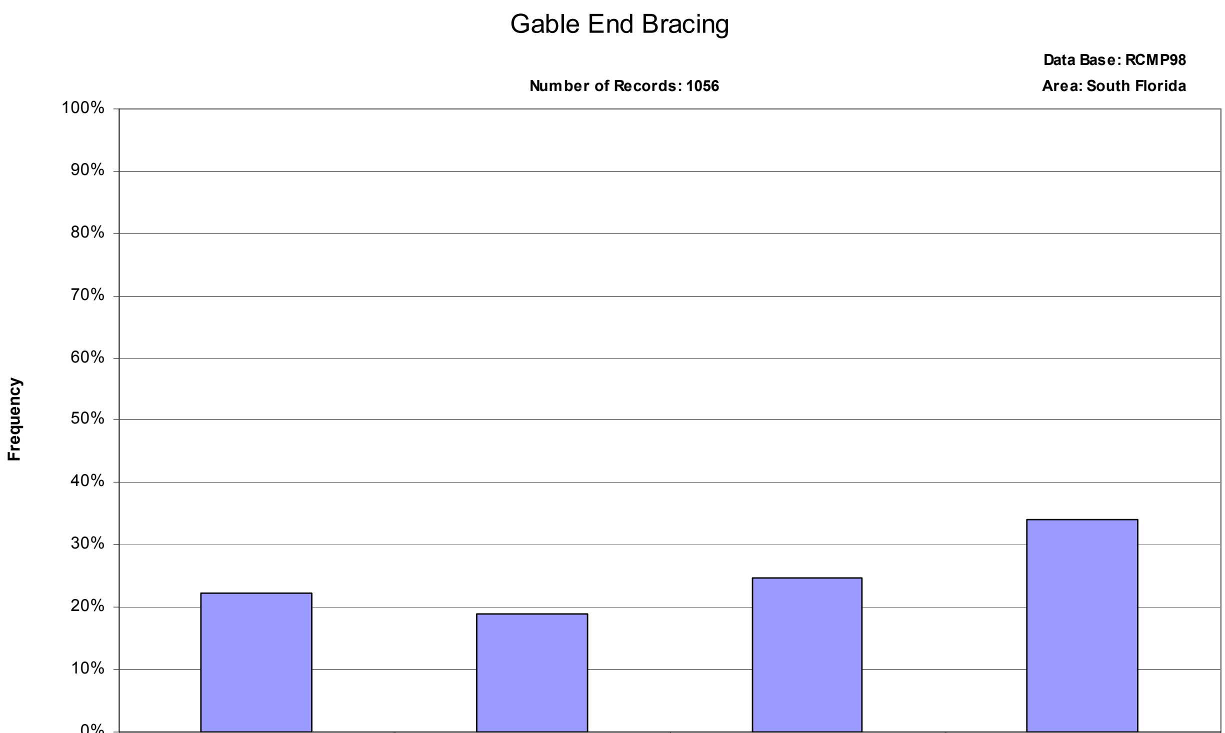
	Dim. Lumber	OSB	Plywood	T&G
Series1	35.80%	0.38%	60.23%	3.60%



	less than or equal to 1/4	greater than 1/4 less than or equal to 1/2	greater than 1/2 less than or equal to 3/4	greater than 3/4 and less than or equal to 1	Unknown
Series1	2%	6%	55%	5%	32%

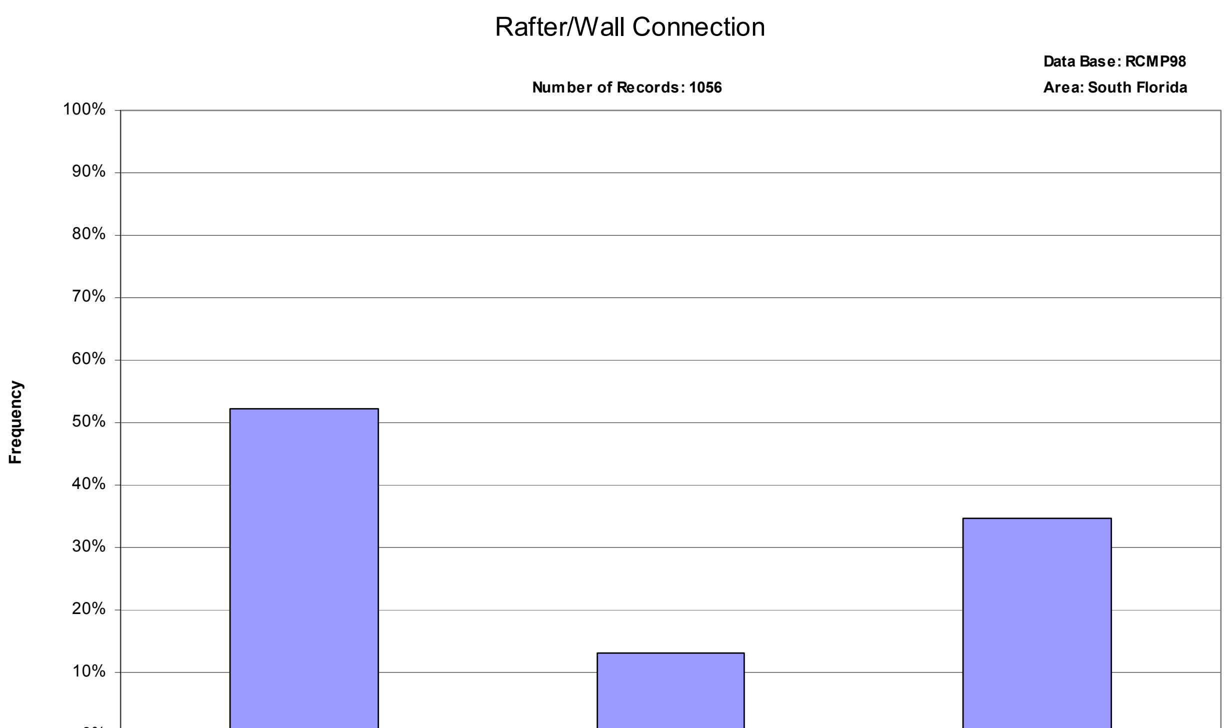

Method of Attachment
Number of Records: 1056
Data Base: RCMP98
Area: South Florida
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Nails
Staples
Unknown
Frequency
71.2%
0.3%
28.5%
Method of Roof Deck Attachment


Roof Deck Nail Size
Number of Records: 1056
Data Base: RCMP98
Area: South Florida
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
6d
8d
10d
Unknown
NA
Series1
8.33%
47.63%
3.31%
40.63%
0.09%
Roof Deck Nail Size



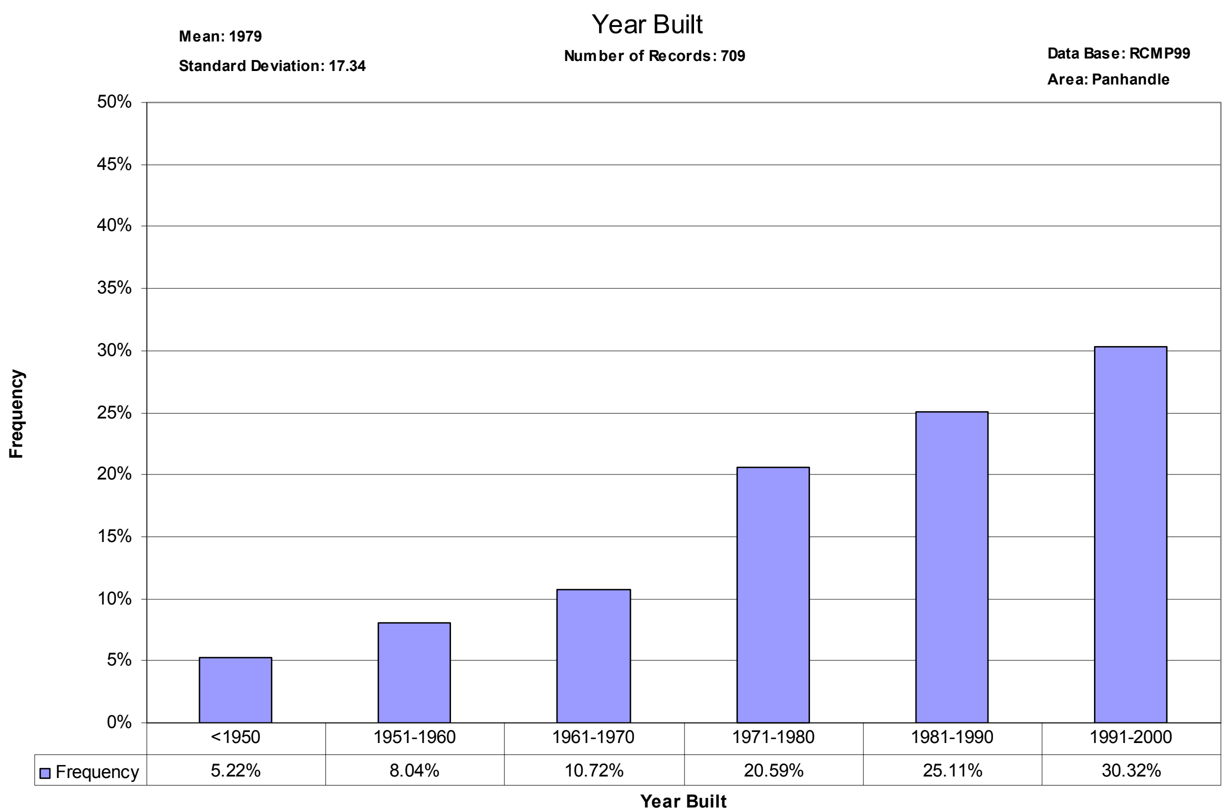
	Yes	No	Unknown	NA
Series1	22%	19%	25%	34%

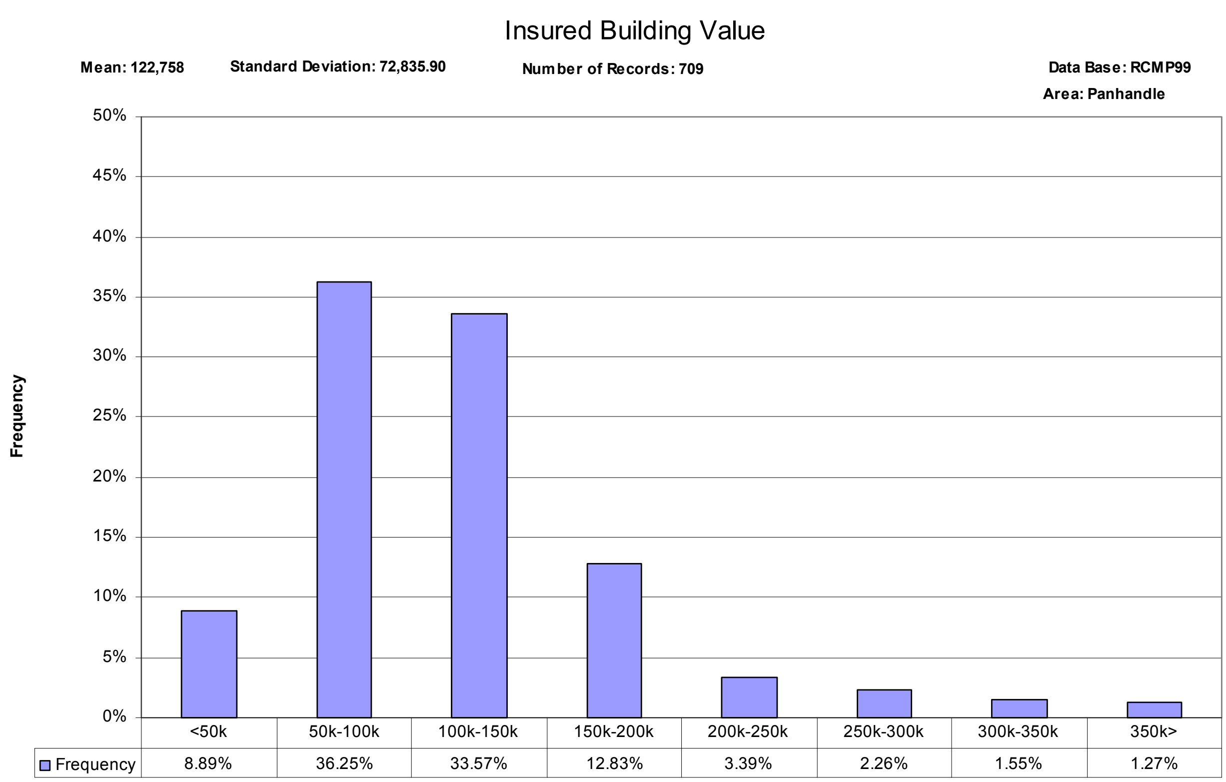
Gable End Bracing

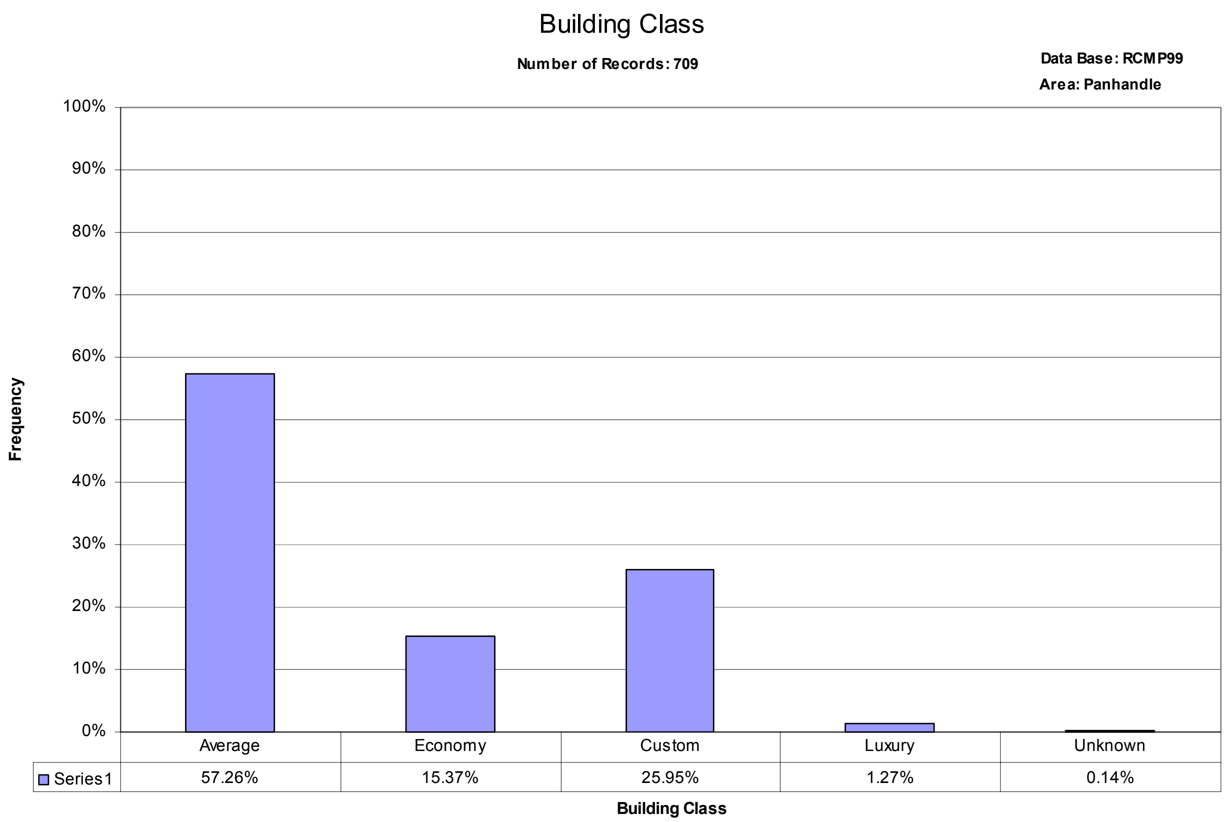


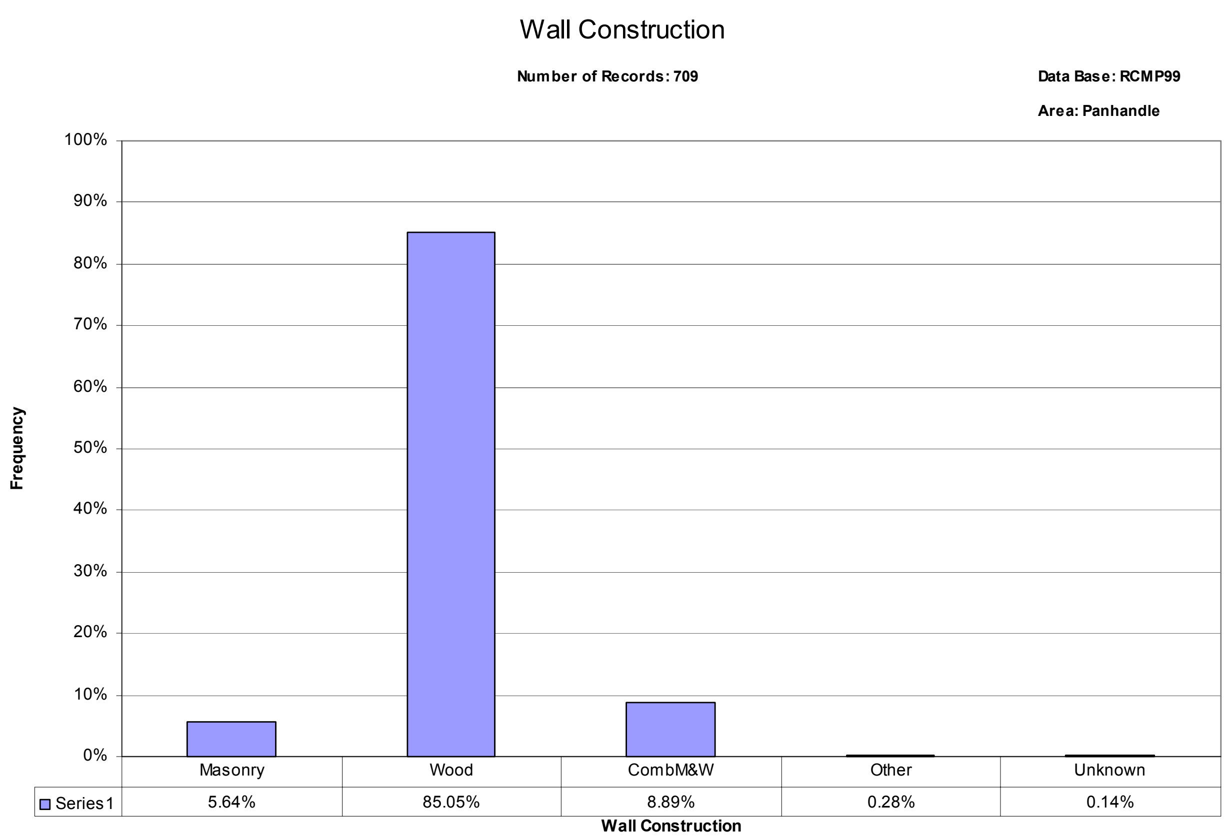
	Yes	No	Unknown
Series1	52.18%	13.16%	34.66%

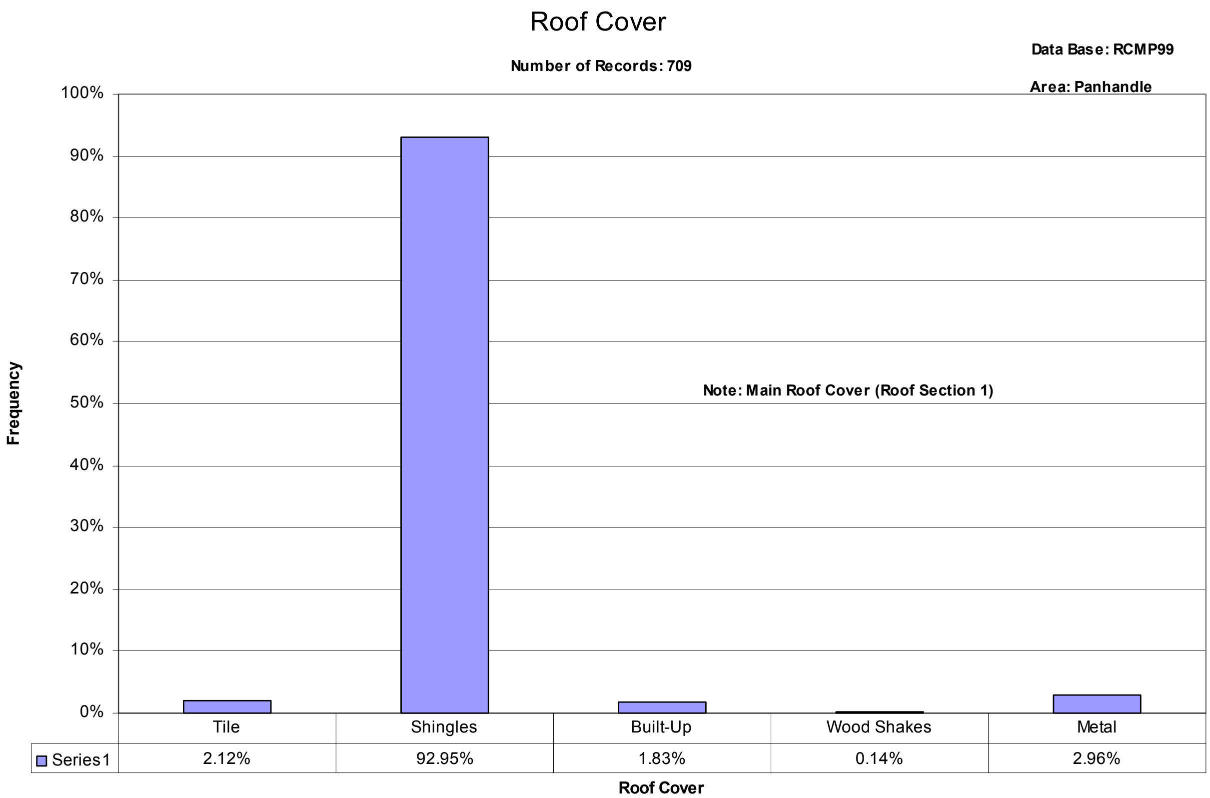
Rafter/Wall Connection

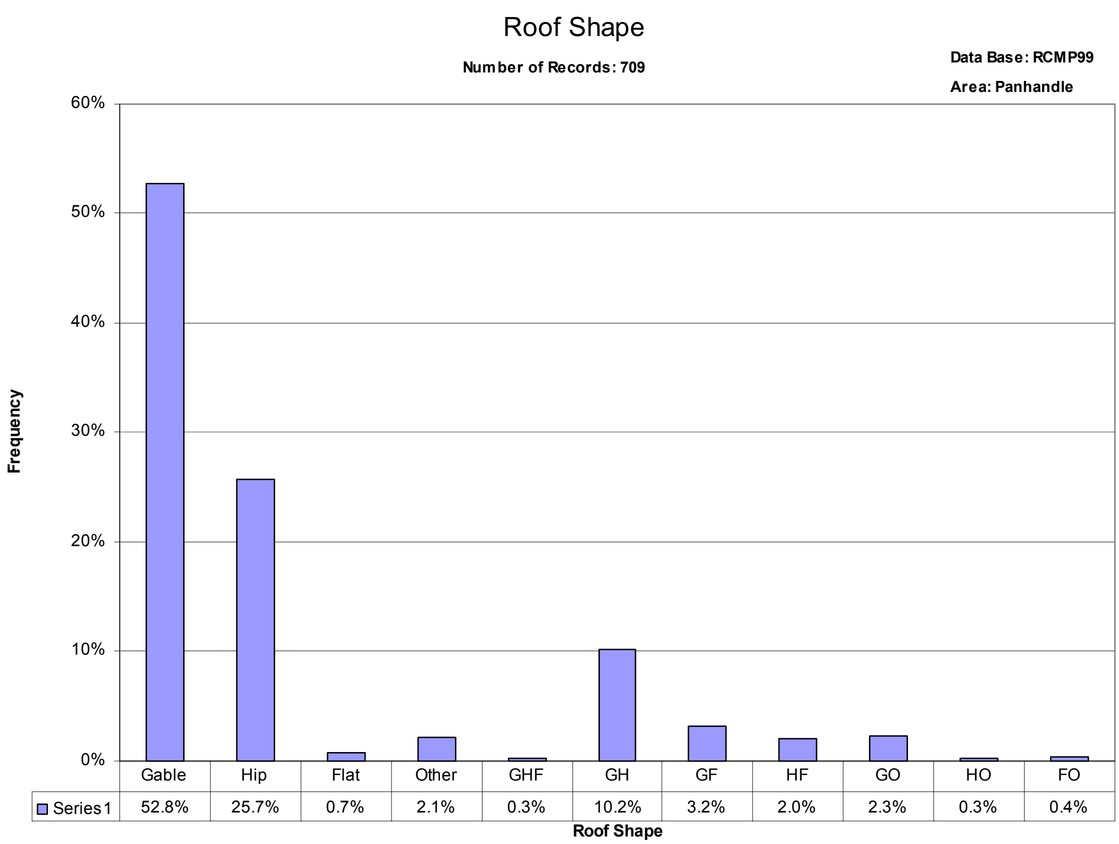

Year Built
Mean: 1979
Standard Deviation: 17.34
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
Frequency
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
<1950
1951-1960
1961-1970
1971-1980
1981-1990
1991-2000
Frequency
5.22%
8.04%
10.72%
20.59%
25.11%
30.32%
Year Built

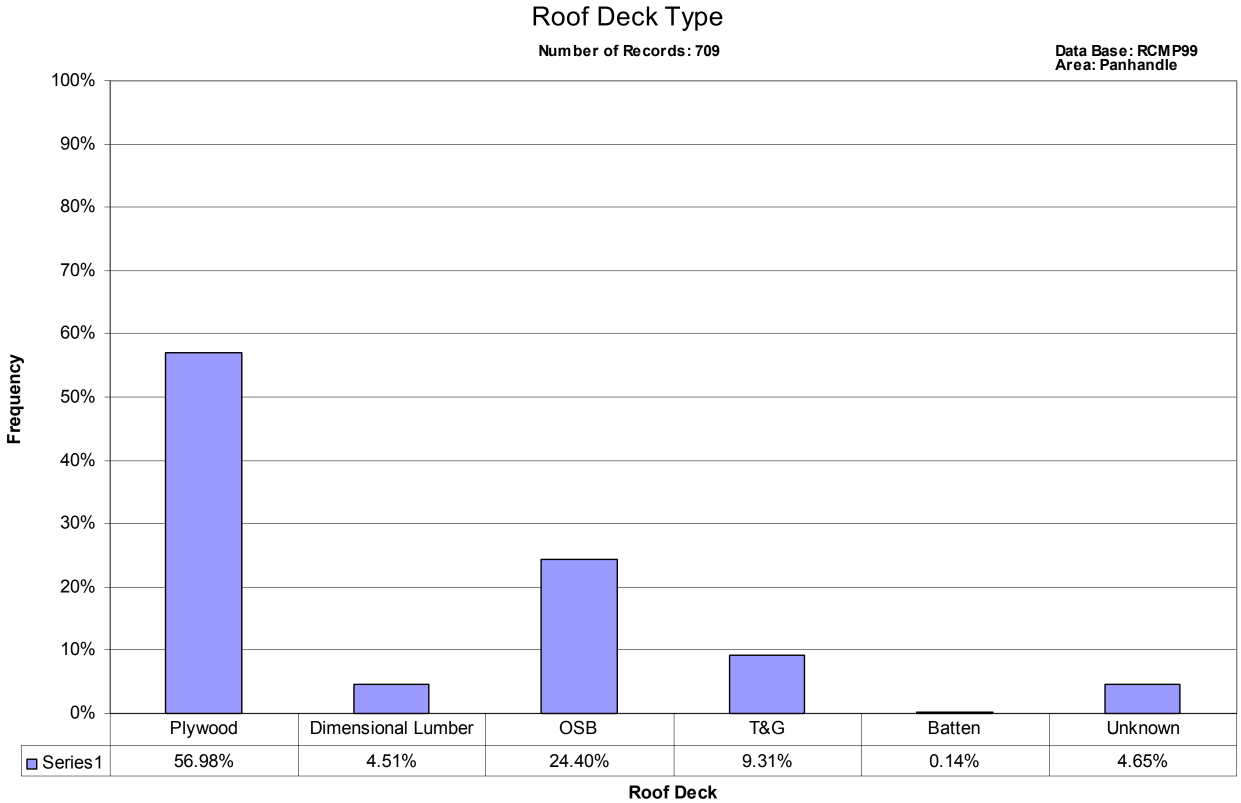

Insured Building Value
Mean: 122,758
Standard Deviation: 72,835.90
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
Frequency
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
<50k
50k-100k
100k-150k
150k-200k
200k-250k
250k-300k
300k-350k
350k>
Frequency
8.89%
36.25%
33.57%
12.83%
3.39%
2.26%
1.55%
1.27%

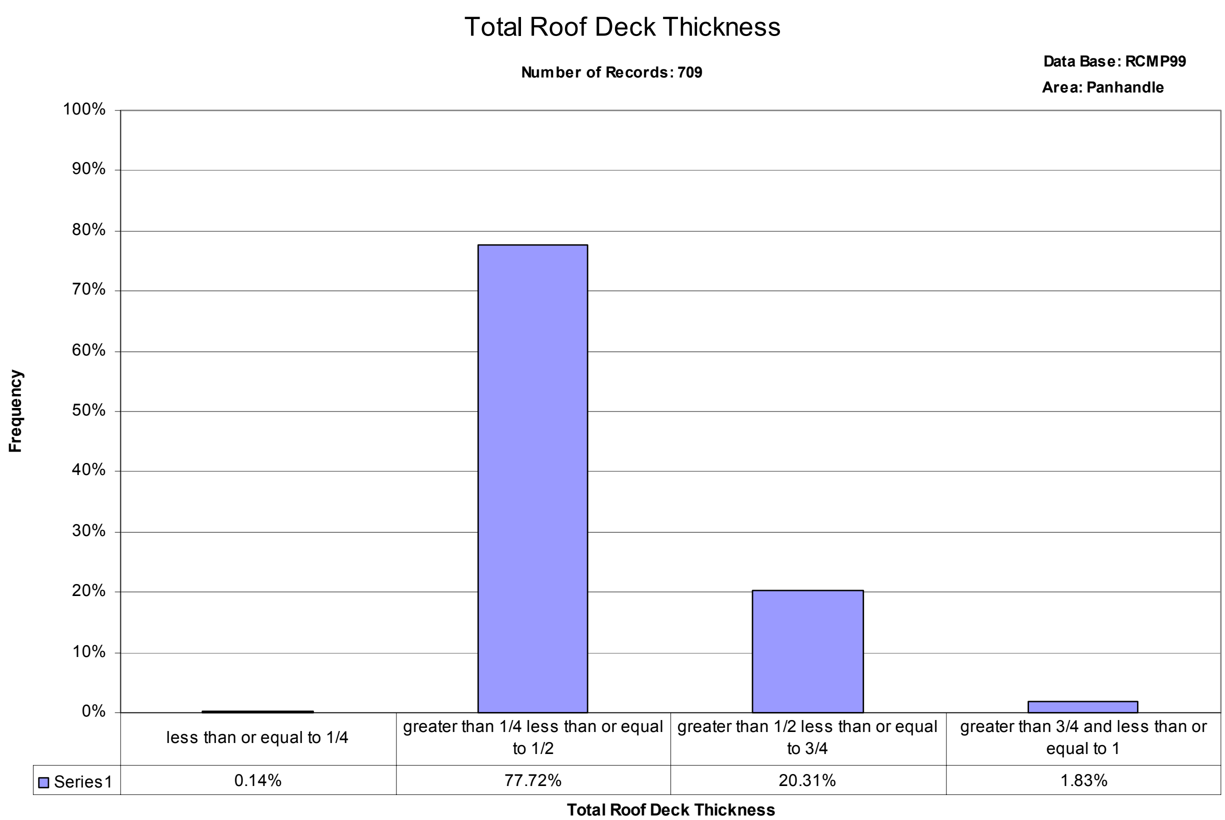

Building Class
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency
Average
Economy
Custom
Luxury
Unknown
Series1
57.26%
15.37%
25.95%
1.27%
0.14%
Building Class


Wall Construction
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency
Masonry
Wood
CombM&W
Other
Unknown
Series1
5.64%
85.05%
8.89%
0.28%
0.14%
Wall Construction


Roof Cover
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Note: Main Roof Cover (Roof Section 1)
Tile
Shingles
Built-Up
Wood Shakes
Metal
Series1
2.12%
92.95%
1.83%
0.14%
2.96%
Roof Cover


Roof Shape
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
Frequency
60%
50%
40%
30%
20%
10%
0%
Gable
Hip
Flat
Other
GHF
GH
GF
HF
GO
HO
FO
Series1
52.8%
25.7%
0.7%
2.1%
0.3%
10.2%
3.2%
2.0%
2.3%
0.3%
0.4%
Roof Shape


Roof Deck Type
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Plywood
Dimensional Lumber
OSB
T&G
Batten
Unknown
Series1
56.98%
4.51%
24.40%
9.31%
0.14%
4.65%
Roof Deck

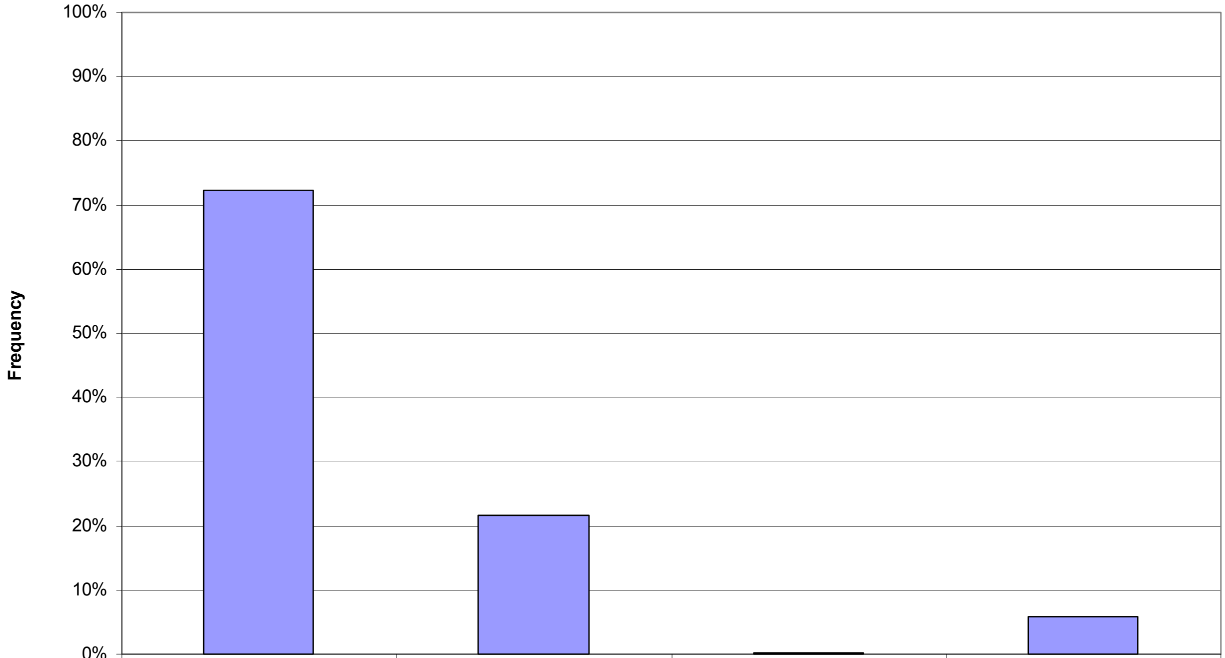

Total Roof Deck Thickness
Number of Records: 709
Data Base: RCMP99
Area: Panhandle
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
less than or equal to 1/4
greater than 1/4 less than or equal to 1/2
greater than 1/2 less than or equal to 3/4
greater than 3/4 and less than or equal to 1
Series1
0.14%
77.72%
20.31%
1.83%
Total Roof Deck Thickness

Method of Attachment

Data Base: RCMP99

Area: Panhandle

Number of Records: 709



	Nails	Staples	Screws	Unknown
Series1	72.36%	21.72%	0.14%	5.78%

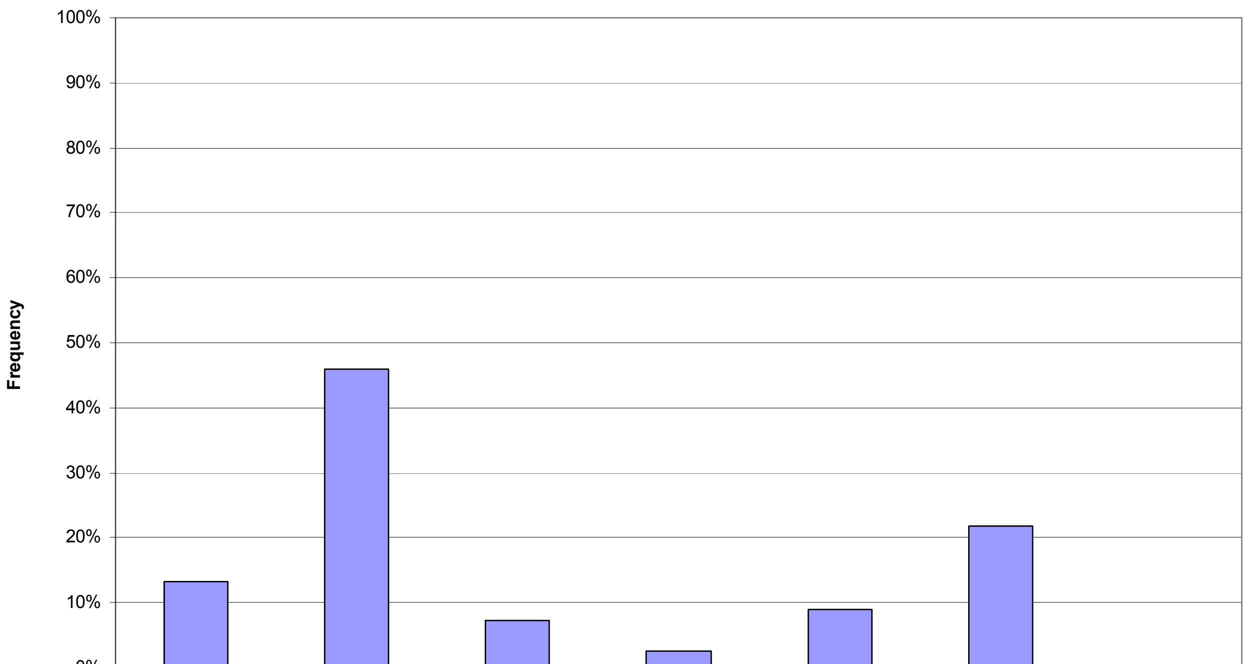
Method of Roof Deck Attachment

Roof Deck Nail Size

Data Base: RCMP99

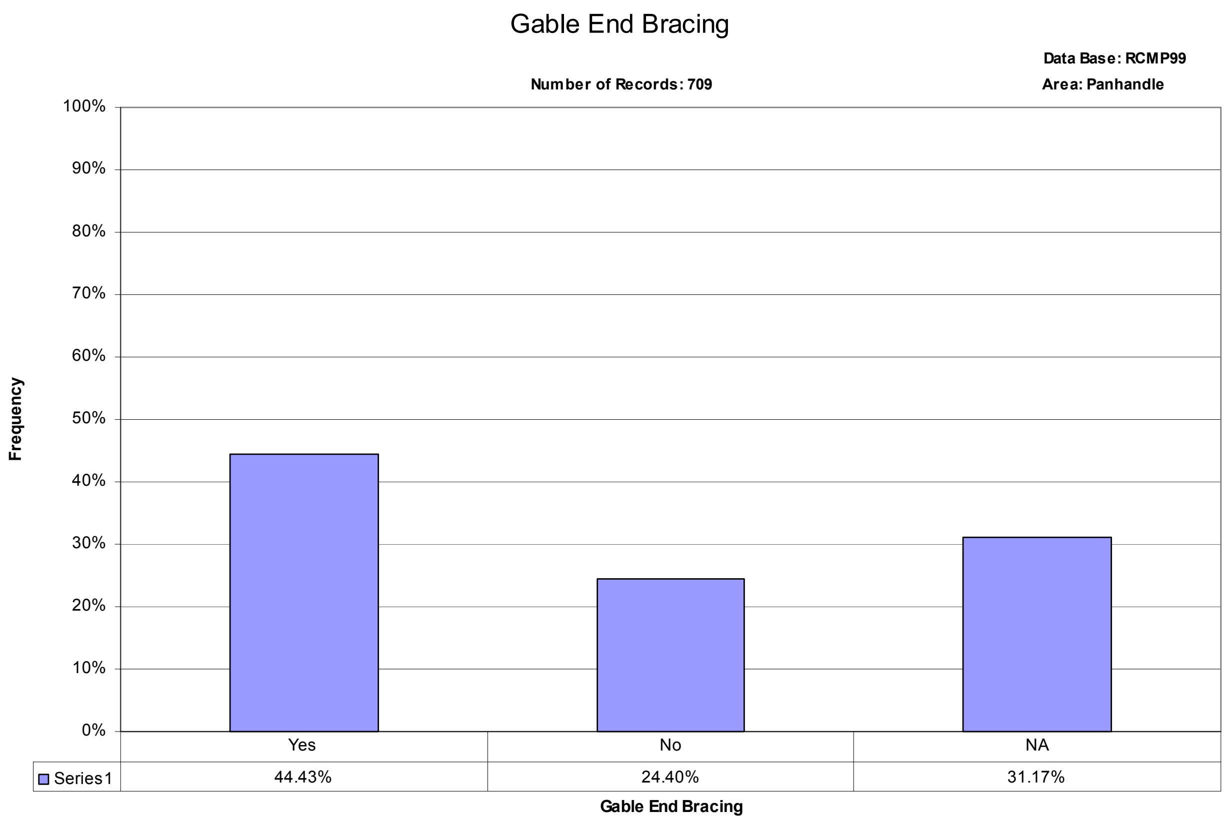
Area: Panhandle

Number of Records: 709

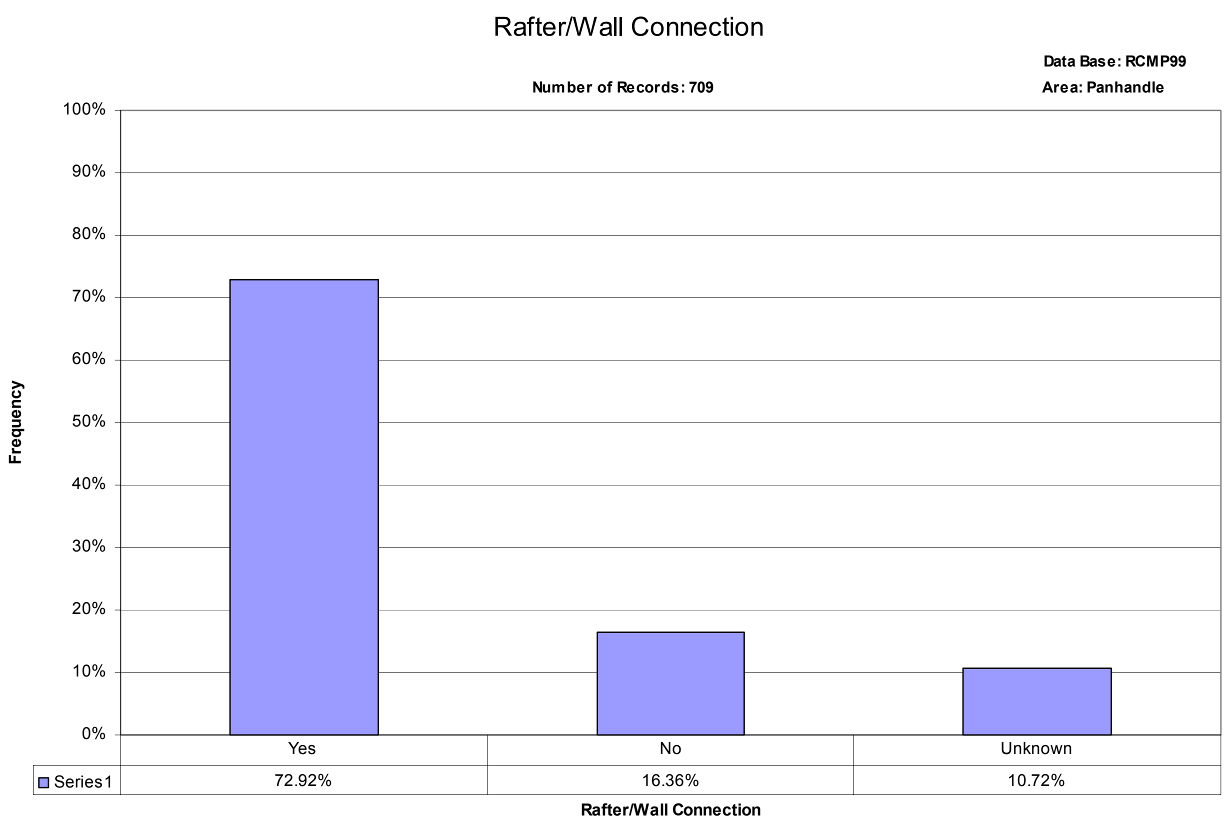


	6d	8d	10d	12d	Unknown	Staples	Screws
Series1	13.26%	45.98%	7.33%	2.54%	9.03%	21.72%	0.14%

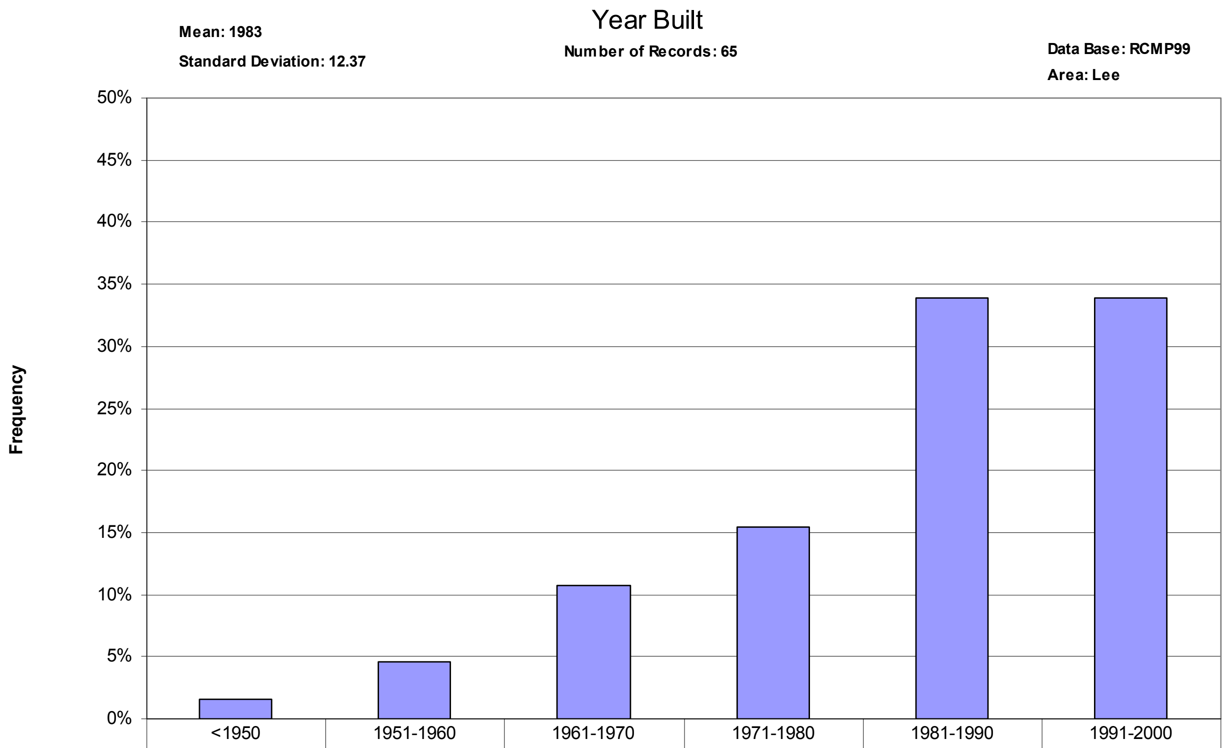
Roof Deck Nail Size



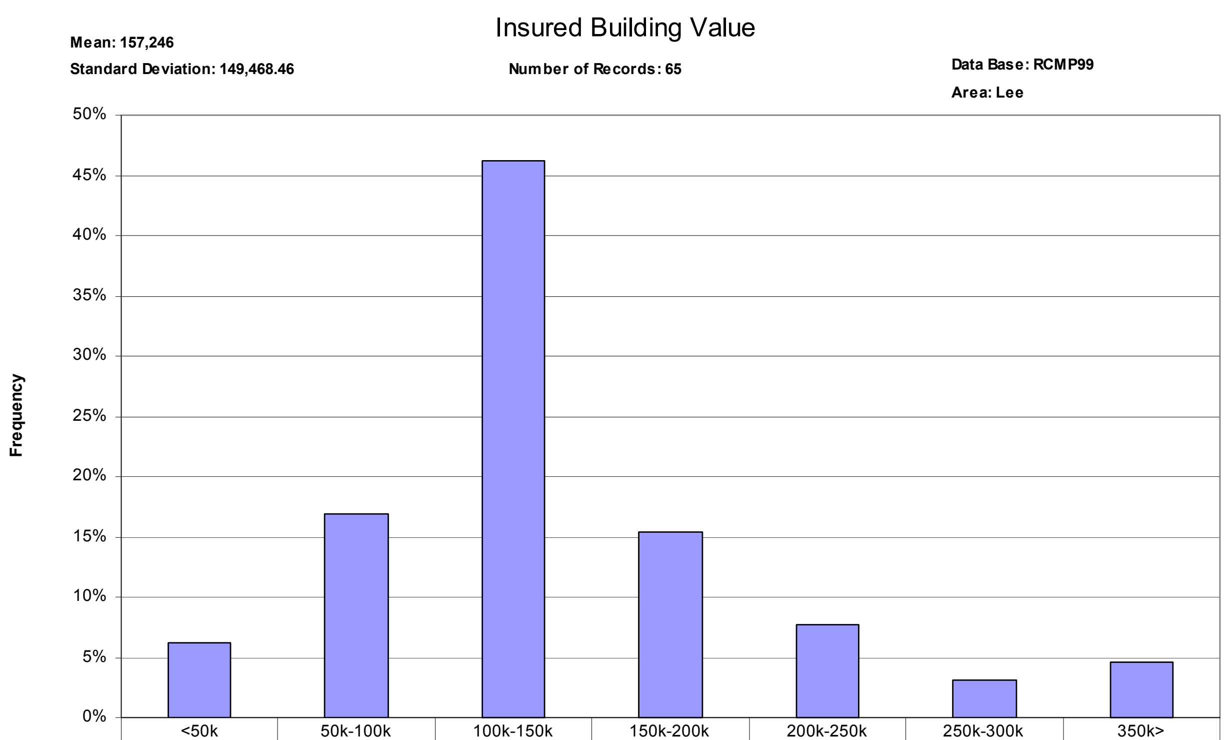
	Yes	No	NA
Series1	44.43%	24.40%	31.17%



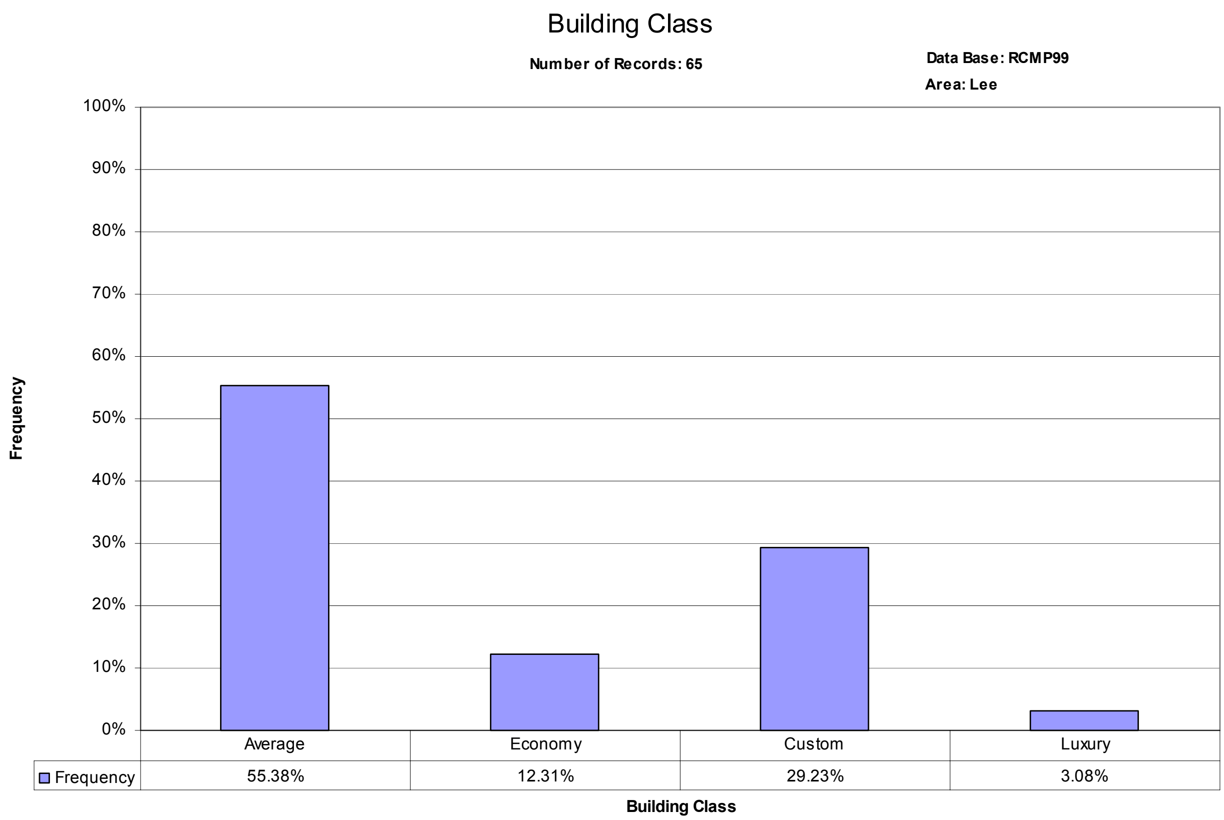
	Yes	No	Unknown
Series1	72.92%	16.36%	10.72%

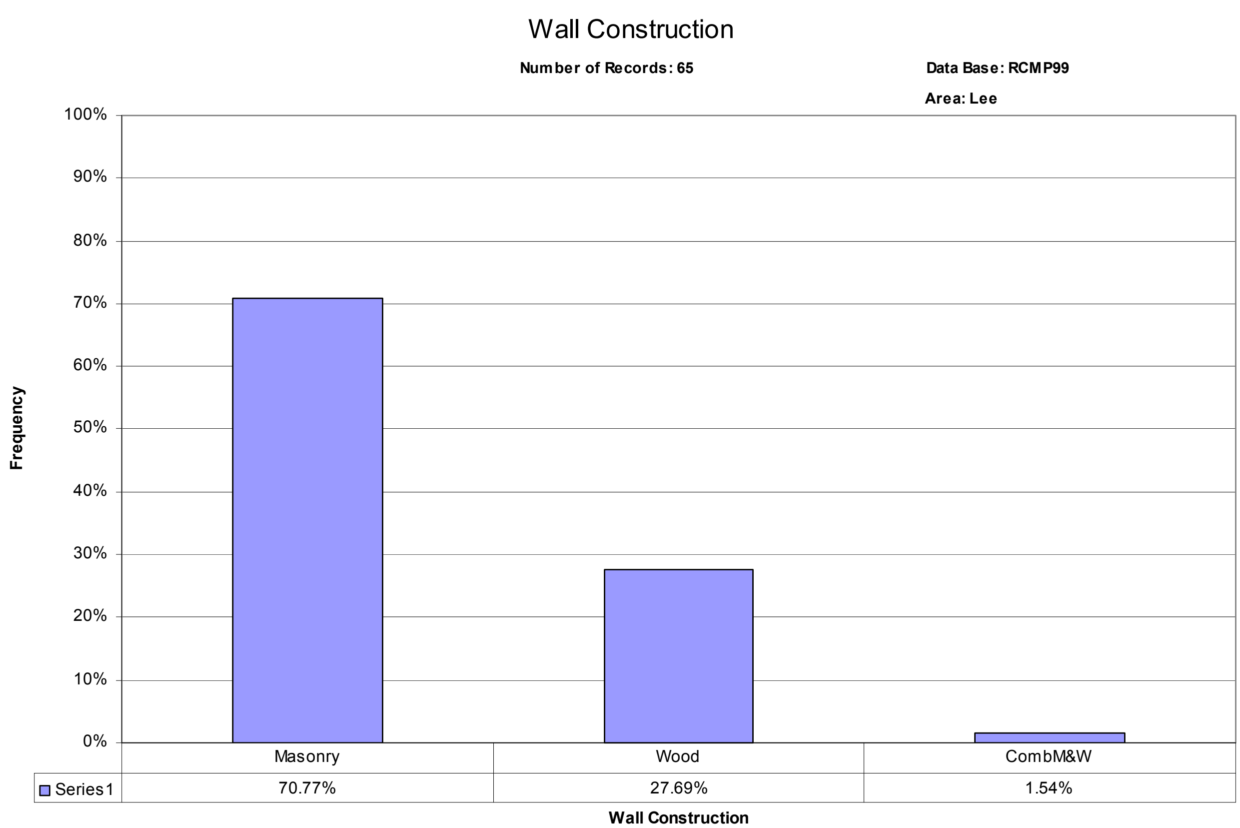


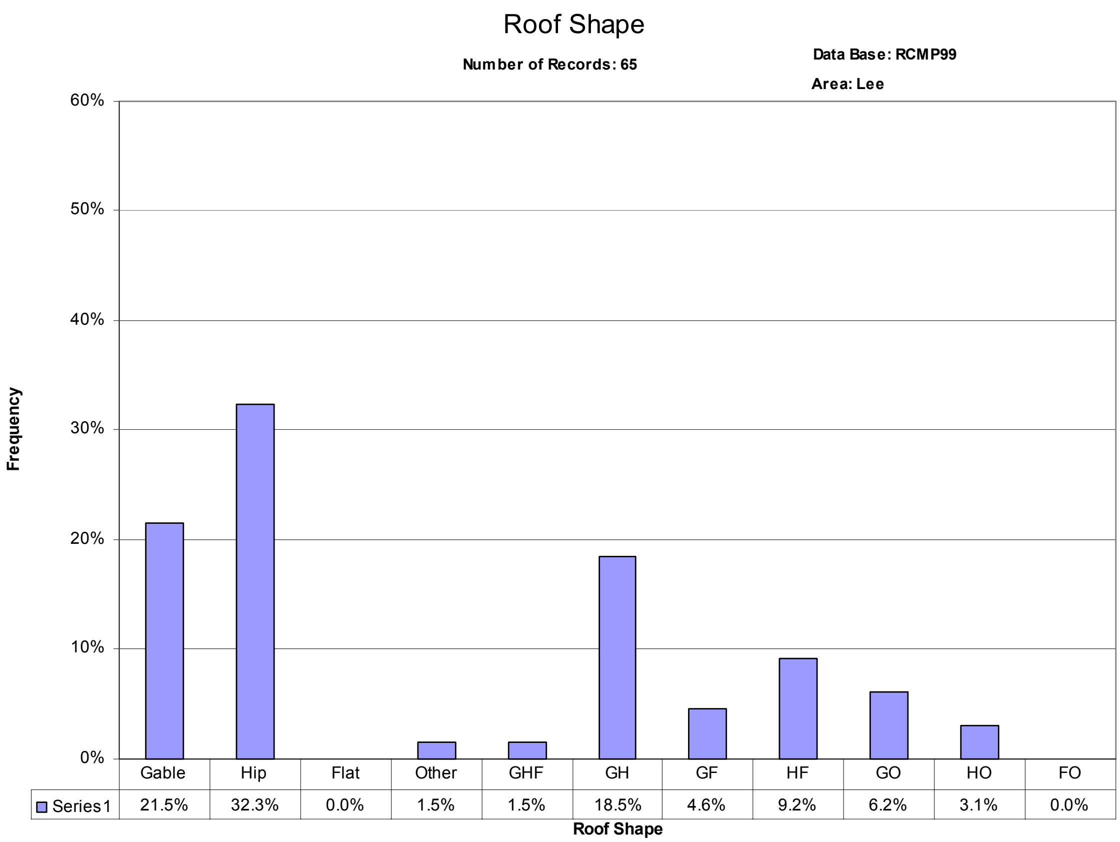
	<1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000
Frequency	1.54%	4.62%	10.77%	15.38%	33.85%	33.85%

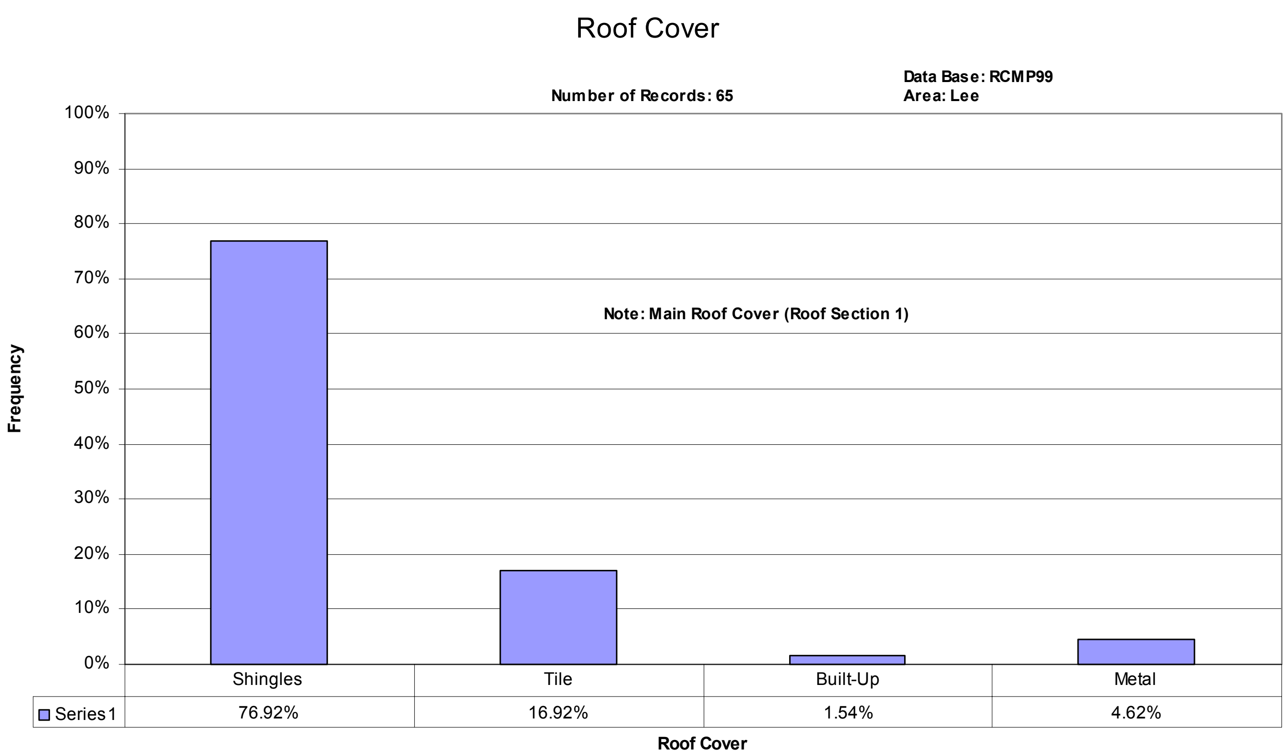


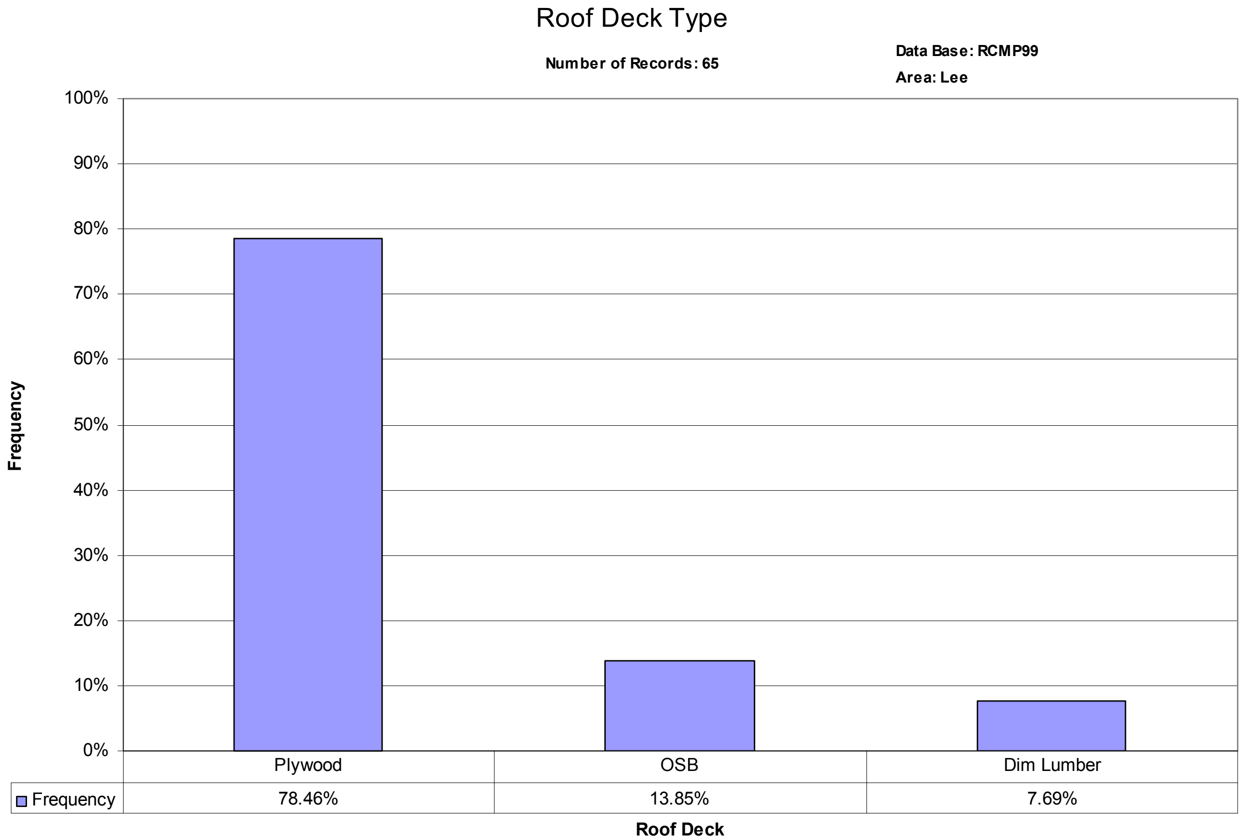
	<50k	50k-100k	100k-150k	150k-200k	200k-250k	250k-300k	350k>
Series1	6.15%	16.92%	46.15%	15.38%	7.69%	3.08%	4.62%

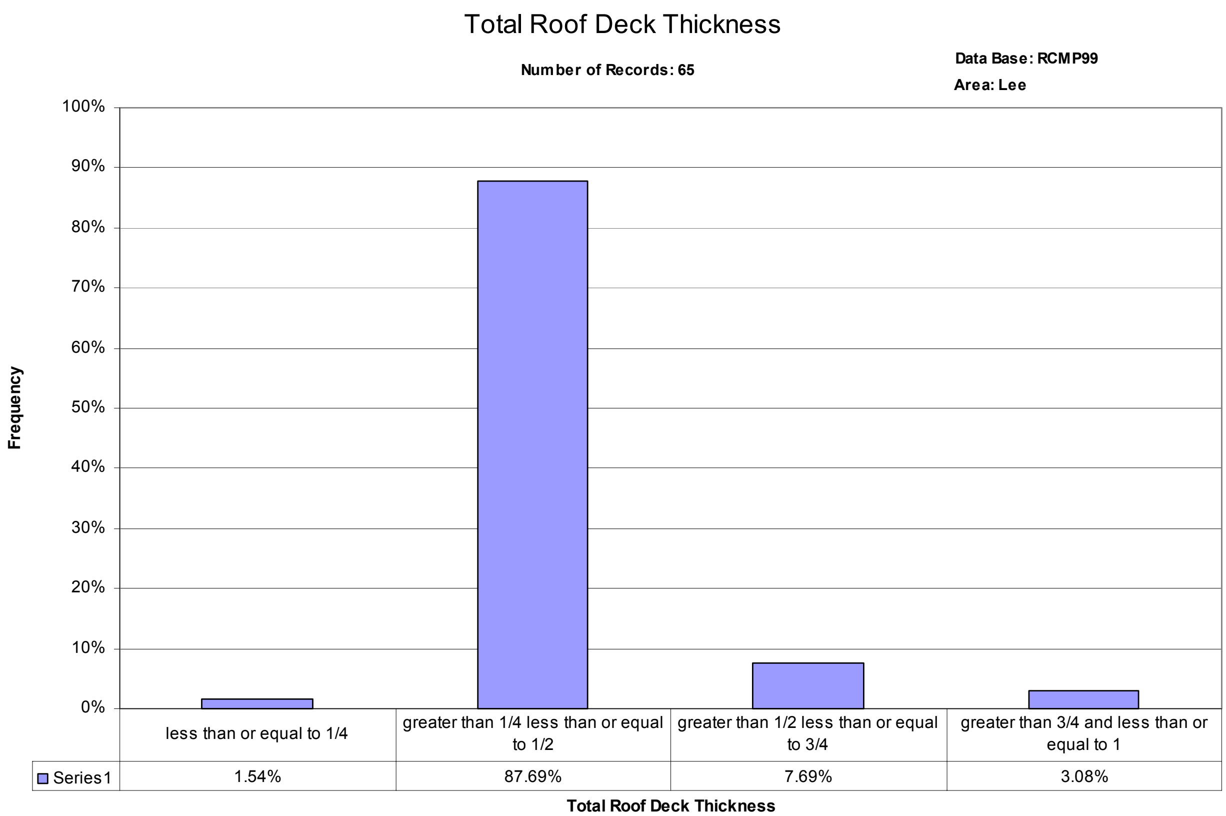

Building Class
Number of Records: 65
Data Base: RCMP99
Area: Lee
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Average
Economy
Custom
Luxury
Frequency
55.38%
12.31%
29.23%
3.08%
Building Class

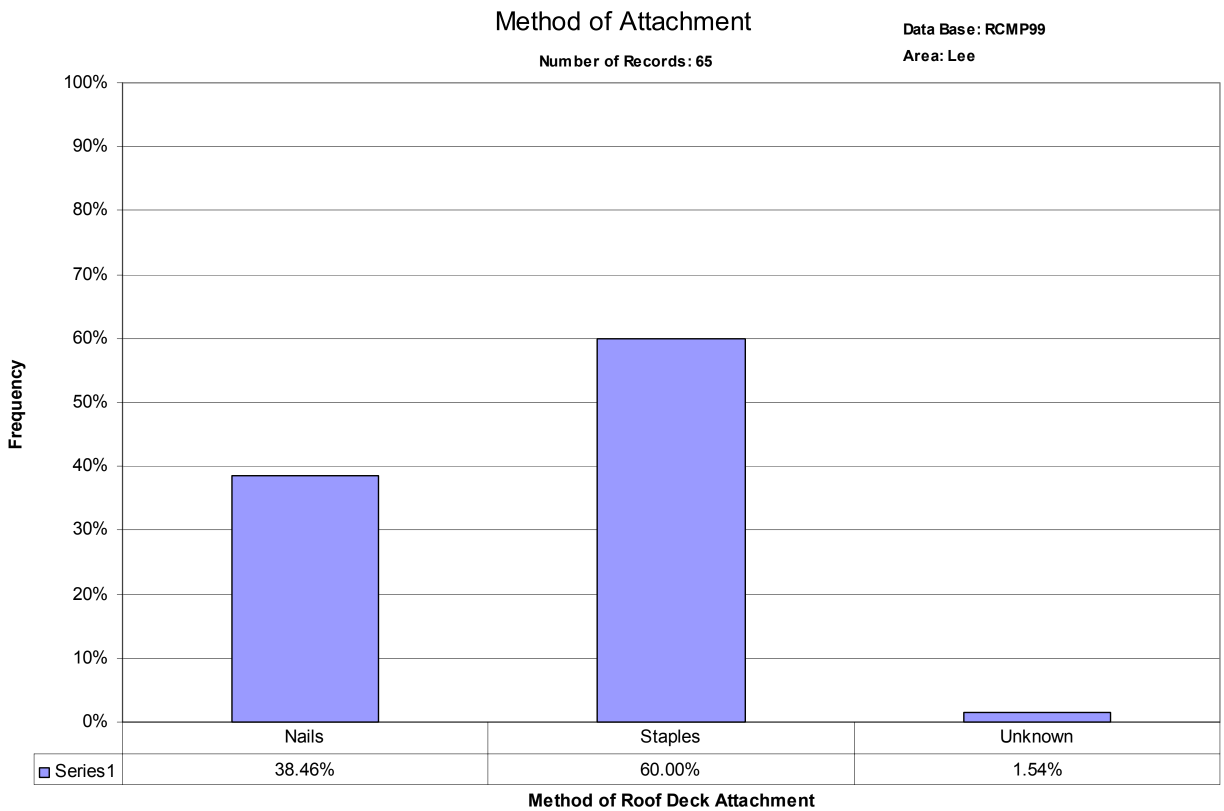

Wall Construction
Number of Records: 65
Data Base: RCMP99
Area: Lee
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Masonry
Wood
CombM&W
Series1
70.77%
27.69%
1.54%
Wall Construction


Roof Shape
Number of Records: 65
Data Base: RCMP99
Area: Lee
60%
50%
40%
30%
20%
10%
0%
Frequency
Gable
Hip
Flat
Other
GHF
GH
GF
HF
GO
HO
FO
Series1
21.5%
32.3%
0.0%
1.5%
1.5%
18.5%
4.6%
9.2%
6.2%
3.1%
0.0%
Roof Shape

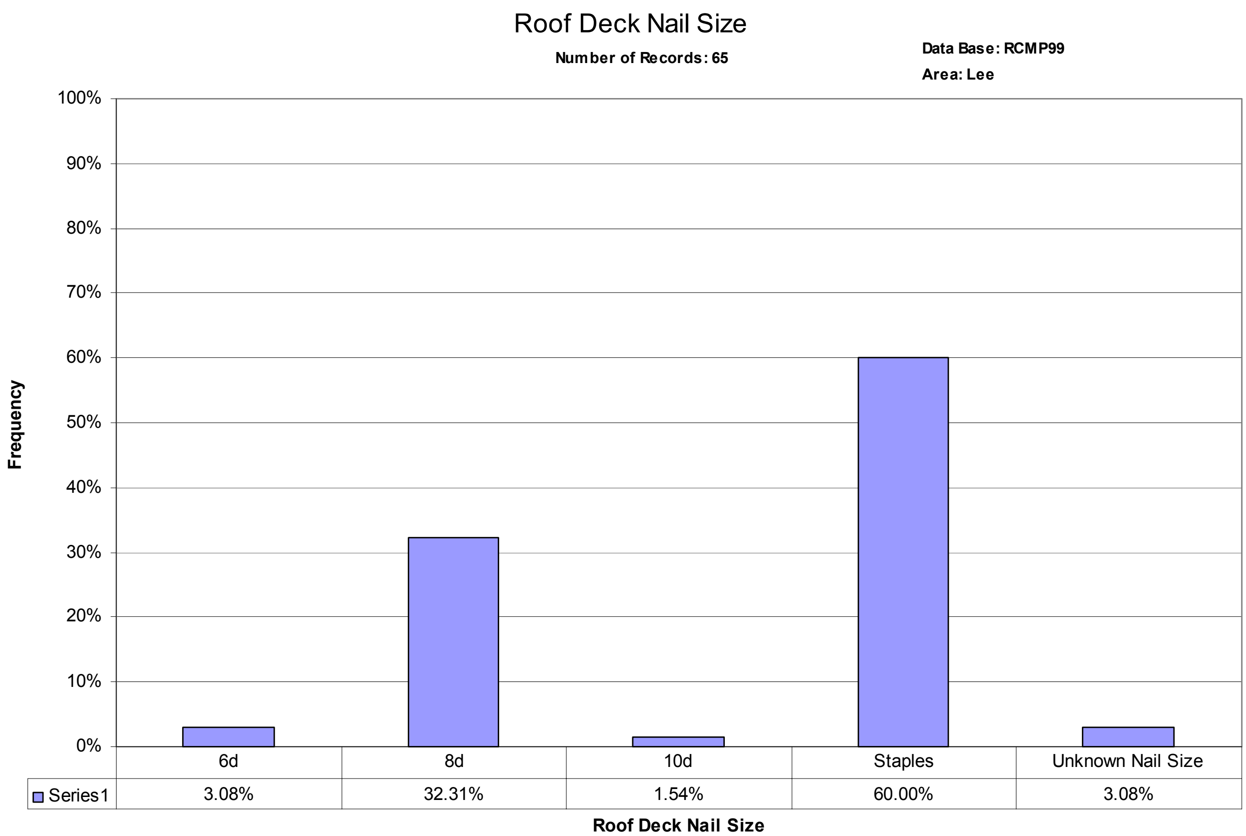

Roof Cover
Number of Records: 65
Data Base: RCMP99
Area: Lee
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency
Note: Main Roof Cover (Roof Section 1)
Shingles
Tile
Built-Up
Metal
Series1
76.92%
16.92%
1.54%
4.62%
Roof Cover


Roof Deck Type
Number of Records: 65
Data Base: RCMP99
Area: Lee
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Plywood
OSB
Dim Lumber
Frequency
78.46%
13.85%
7.69%
Roof Deck

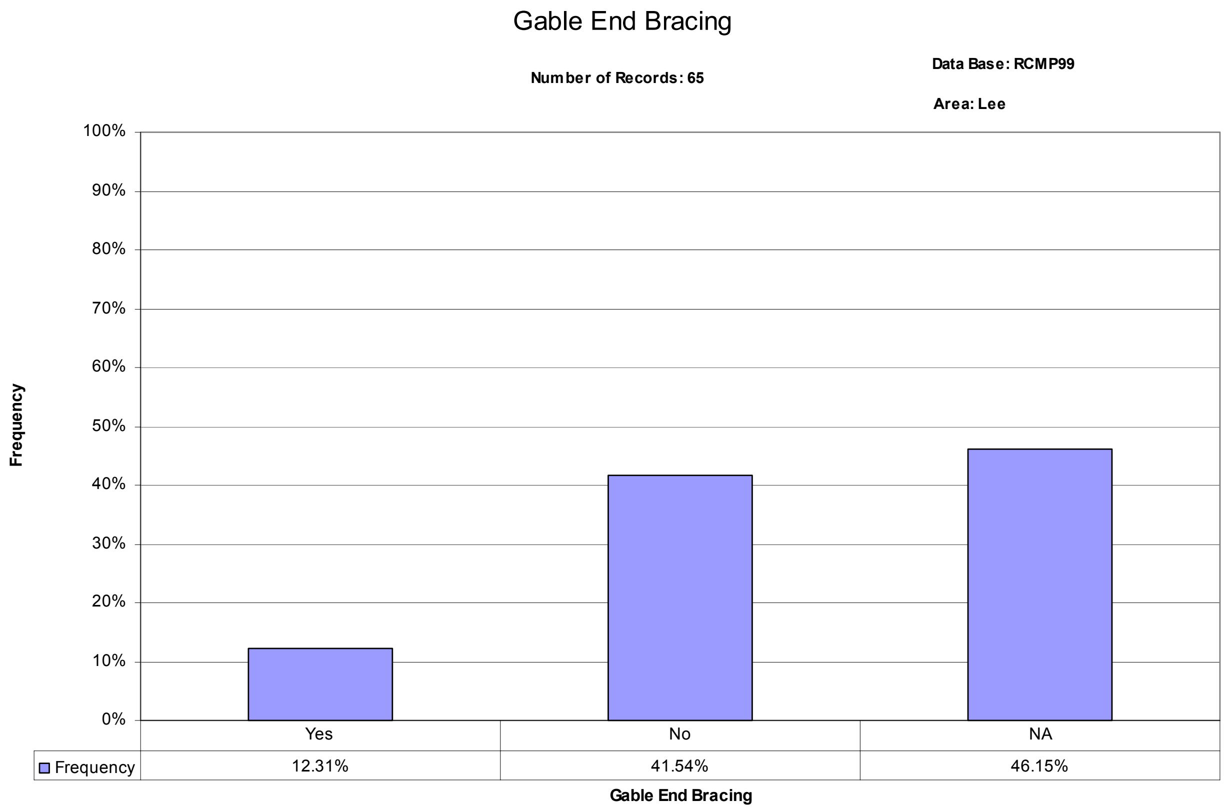

Total Roof Deck Thickness
Number of Records: 65
Data Base: RCMP99
Area: Lee
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
less than or equal to 1/4
greater than 1/4 less than or equal to 1/2
greater than 1/2 less than or equal to 3/4
greater than 3/4 and less than or equal to 1
Series1
1.54%
87.69%
7.69%
3.08%
Total Roof Deck Thickness



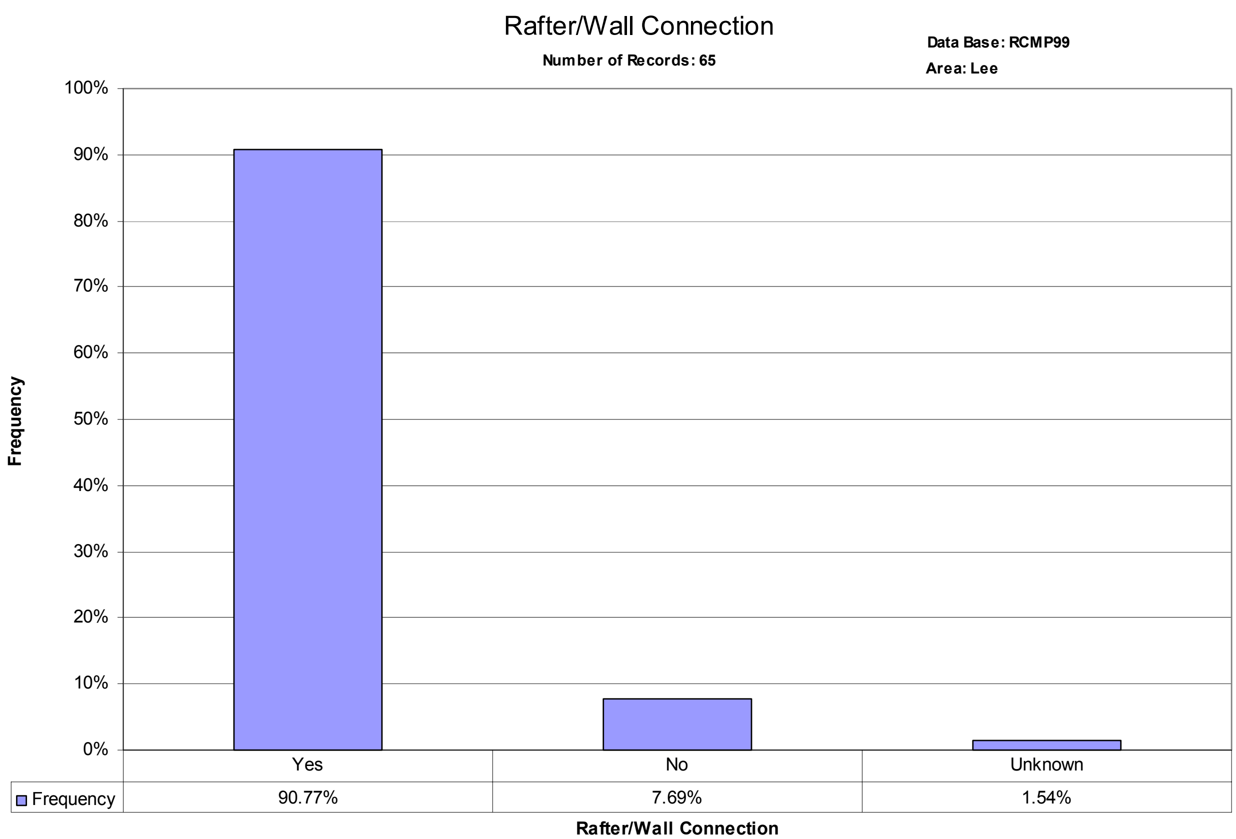
	Nails	Staples	Unknown
Series1	38.46%	60.00%	1.54%



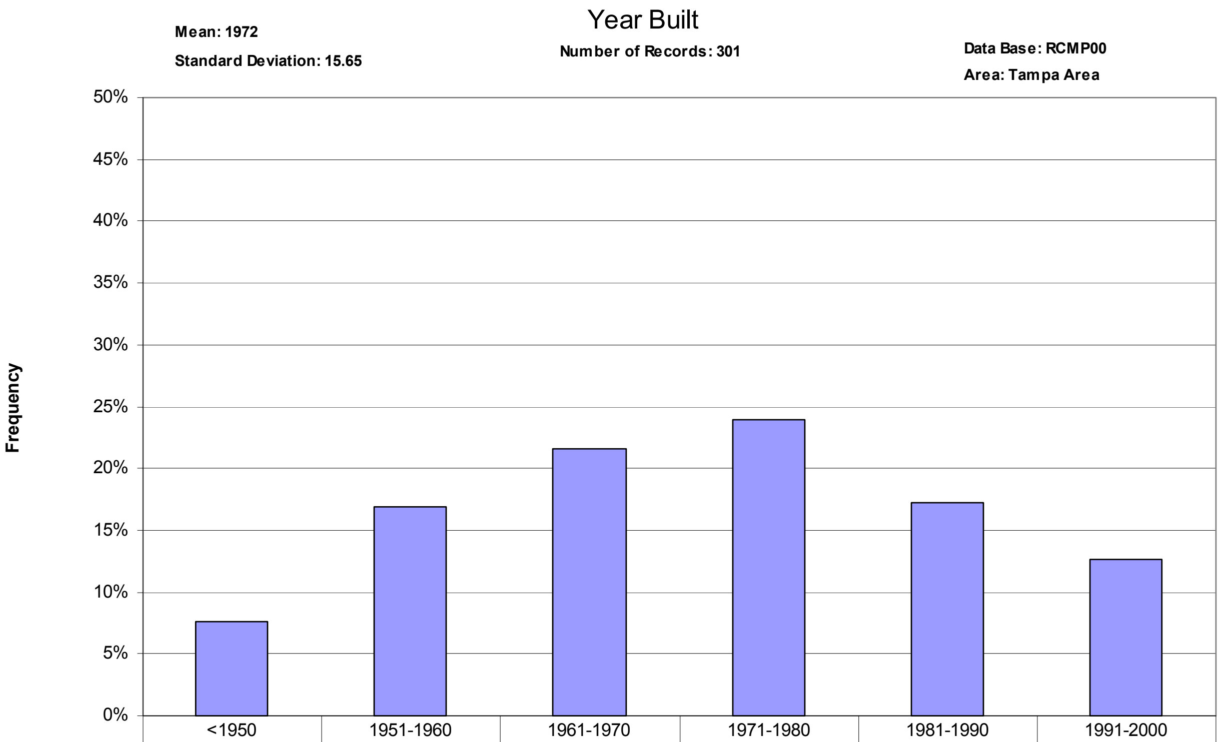
	6d	8d	10d	Staples	Unknown Nail Size
Series1	3.08%	32.31%	1.54%	60.00%	3.08%



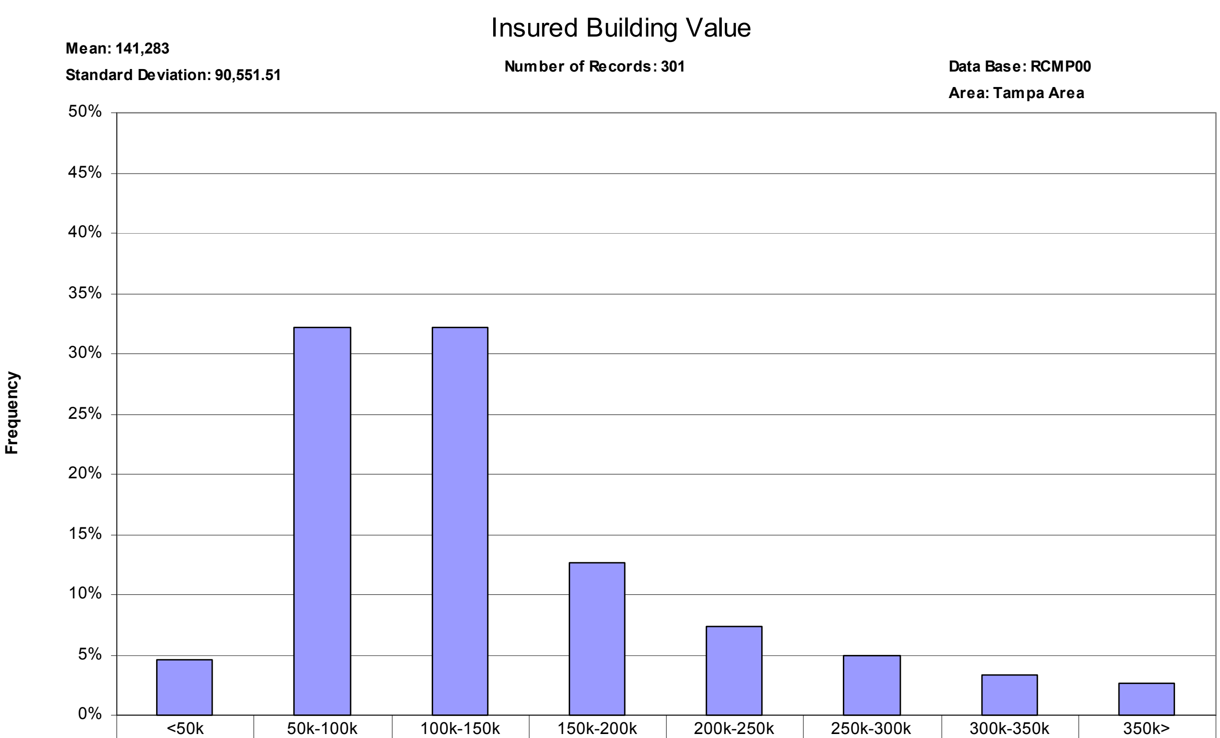
	Yes	No	NA
Frequency	12.31%	41.54%	46.15%



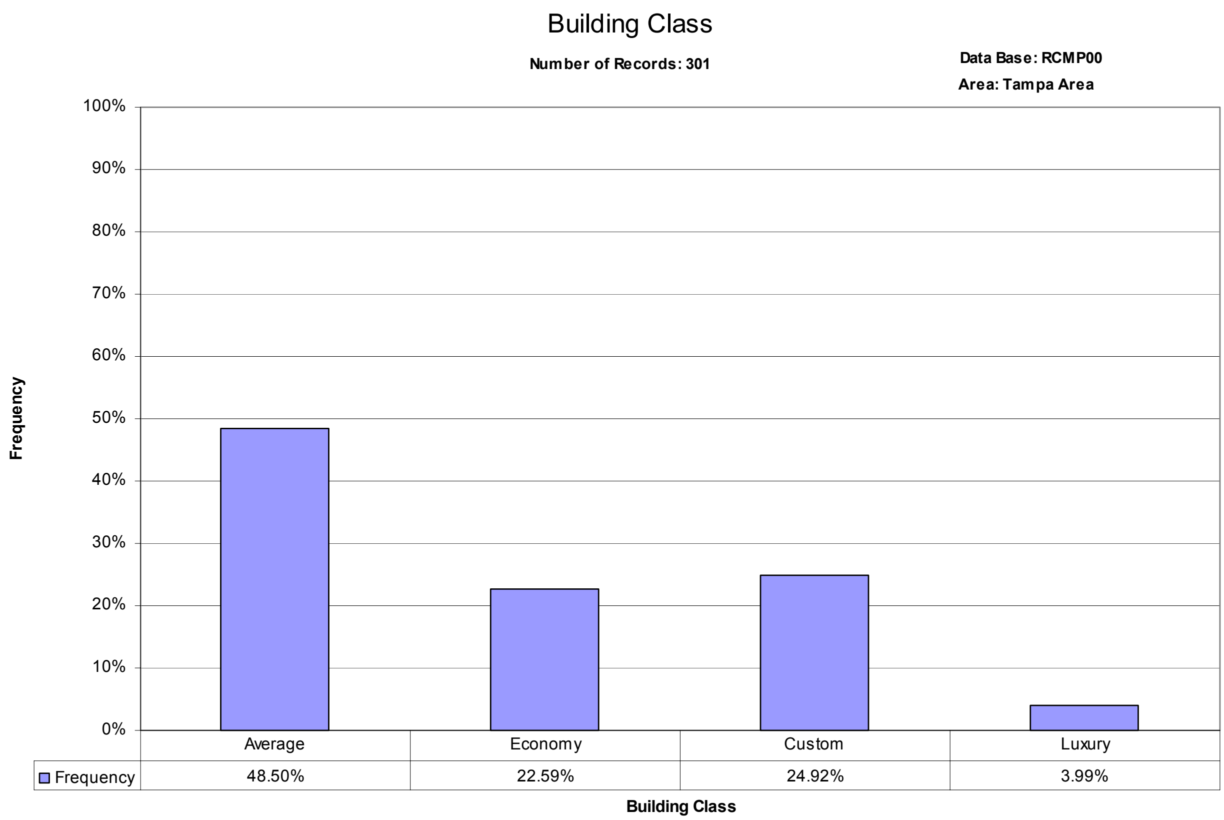
	Yes	No	Unknown
Frequency	90.77%	7.69%	1.54%



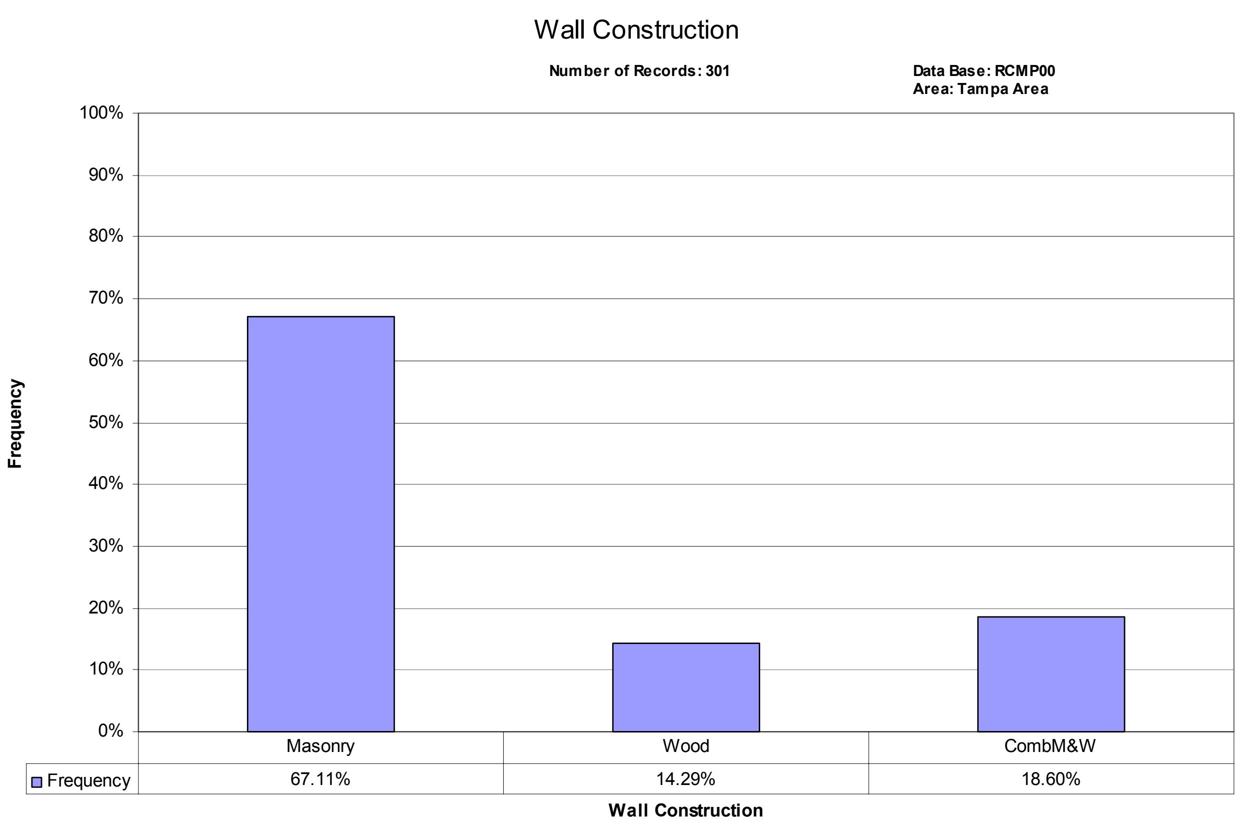
	<1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000
Frequency	7.64%	16.94%	21.59%	23.92%	17.28%	12.62%



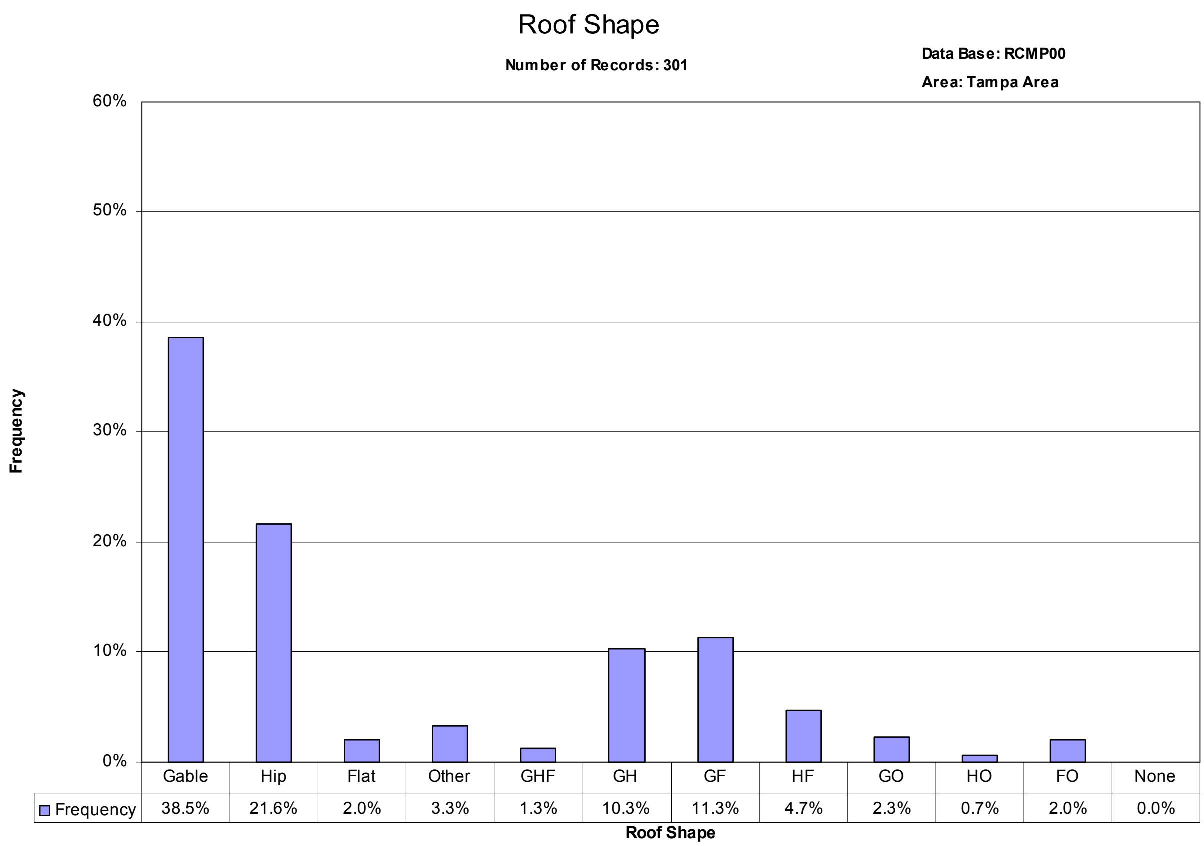
	<50k	50k-100k	100k-150k	150k-200k	200k-250k	250k-300k	300k-350k	350k>
Series1	4.65%	32.23%	32.23%	12.62%	7.31%	4.98%	3.32%	2.66%



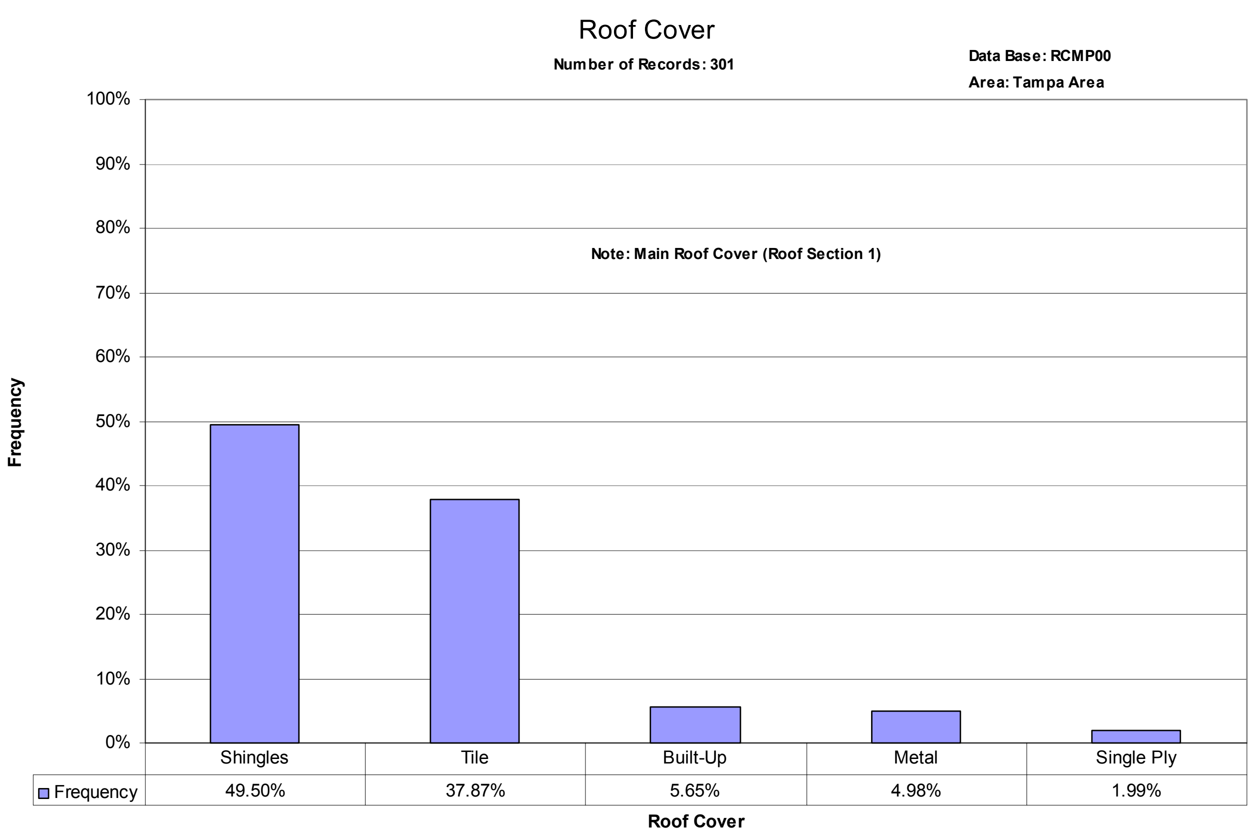
	Average	Economy	Custom	Luxury
Frequency	48.50%	22.59%	24.92%	3.99%



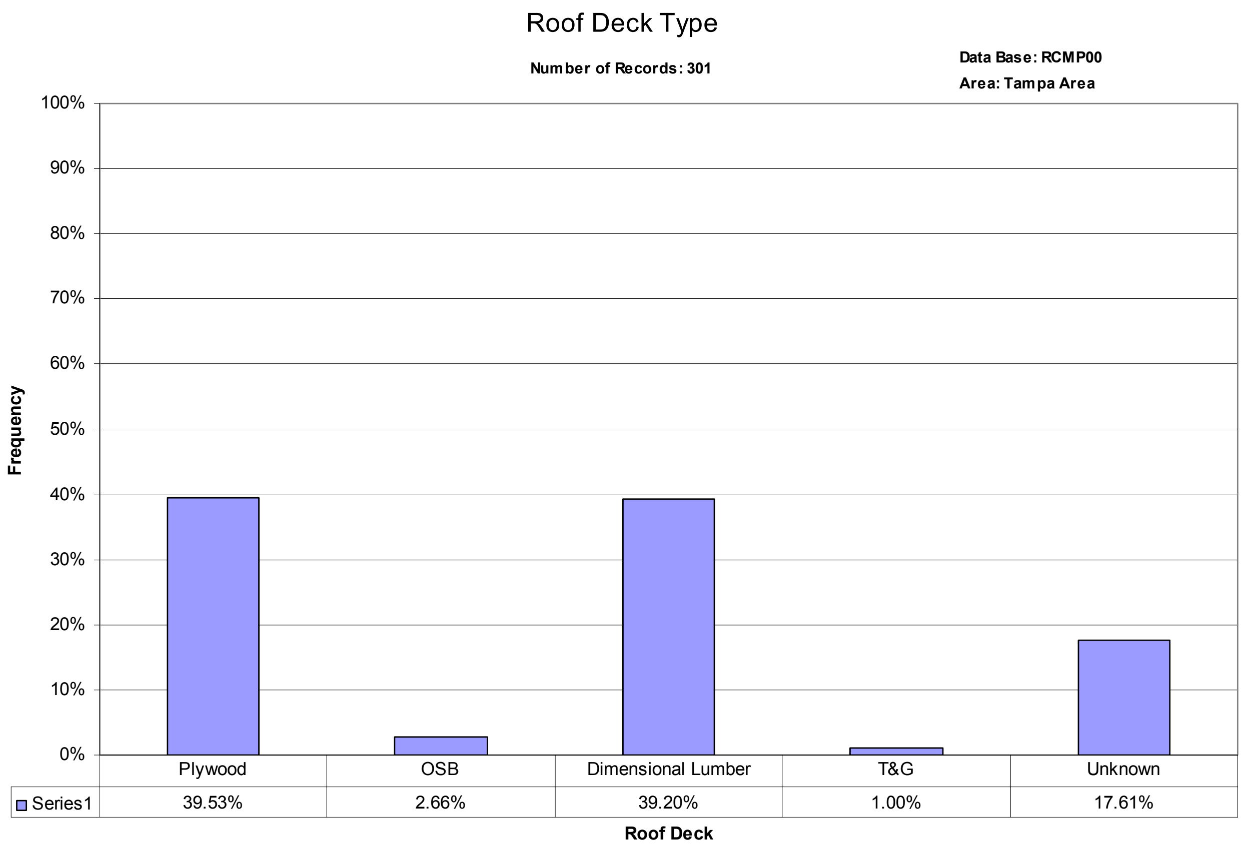
	Masonry	Wood	CombM&W
Frequency	67.11%	14.29%	18.60%

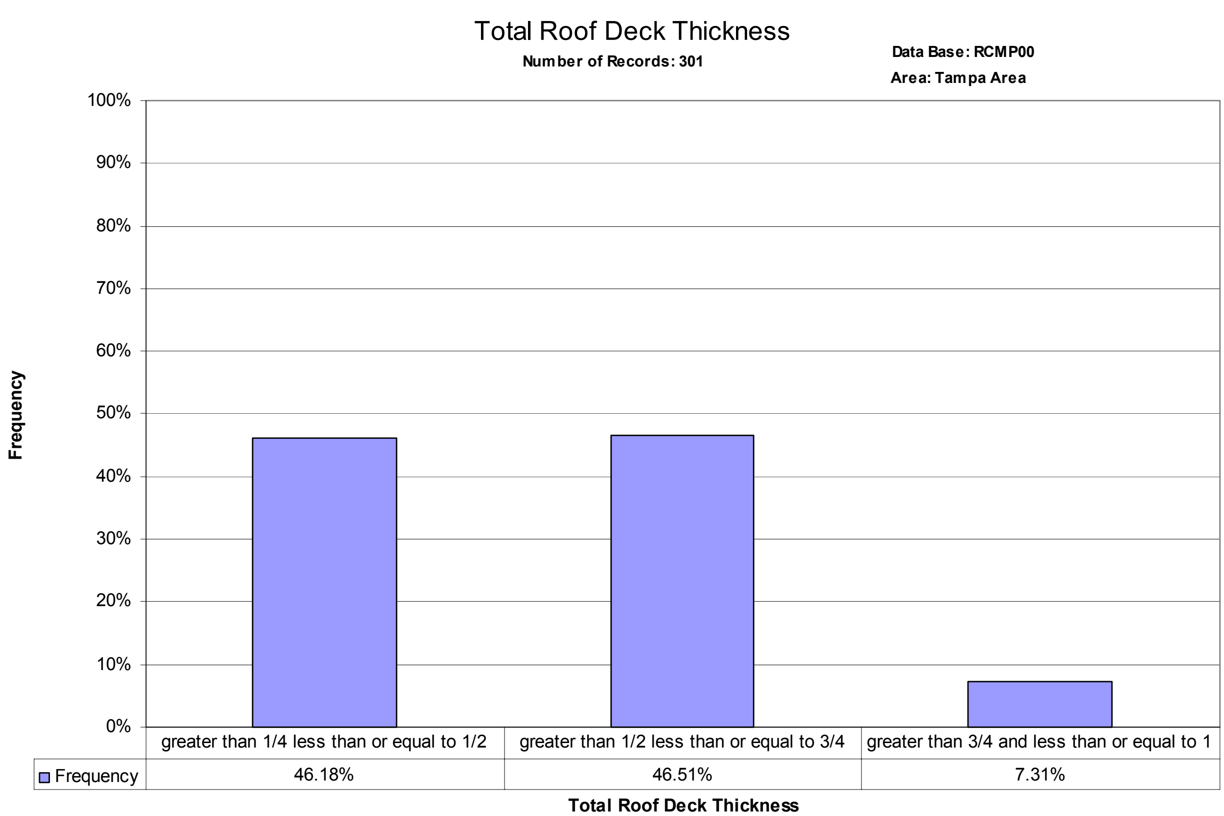


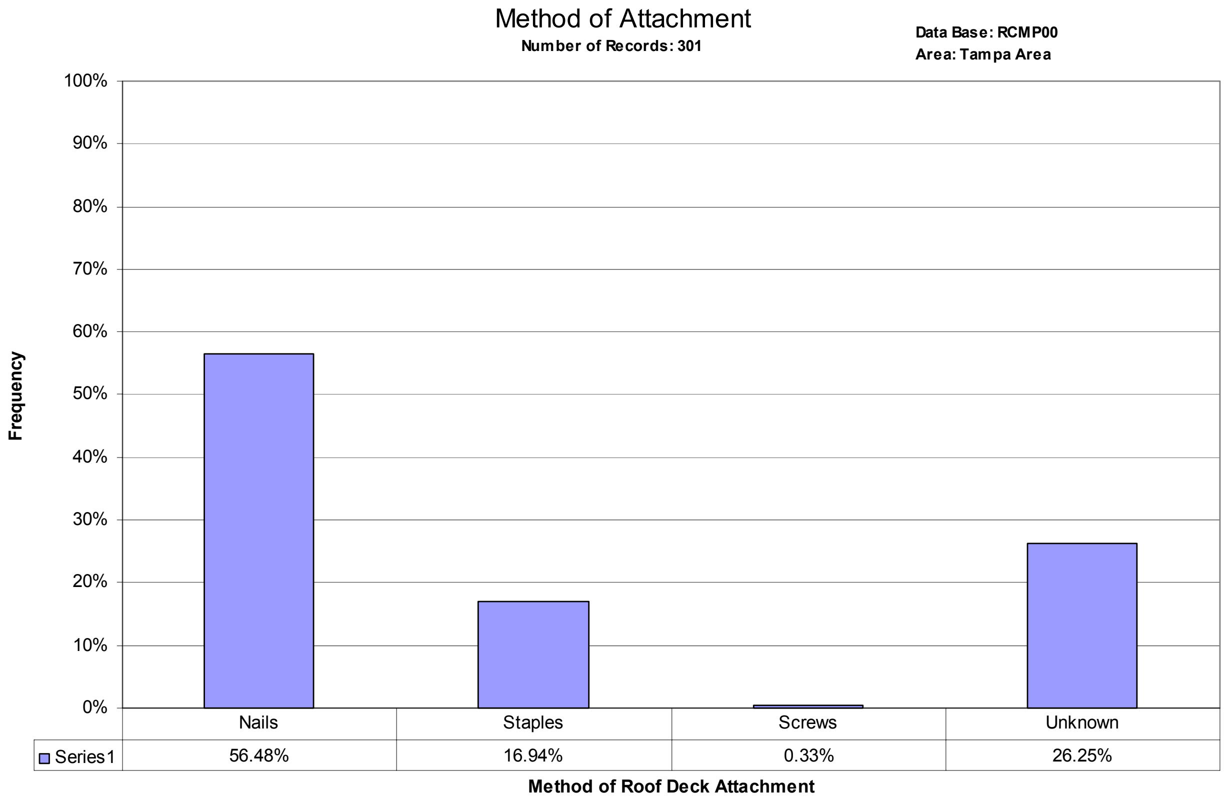
	Gable	Hip	Flat	Other	GHF	GH	GF	HF	GO	HO	FO	None
Frequency	38.5%	21.6%	2.0%	3.3%	1.3%	10.3%	11.3%	4.7%	2.3%	0.7%	2.0%	0.0%



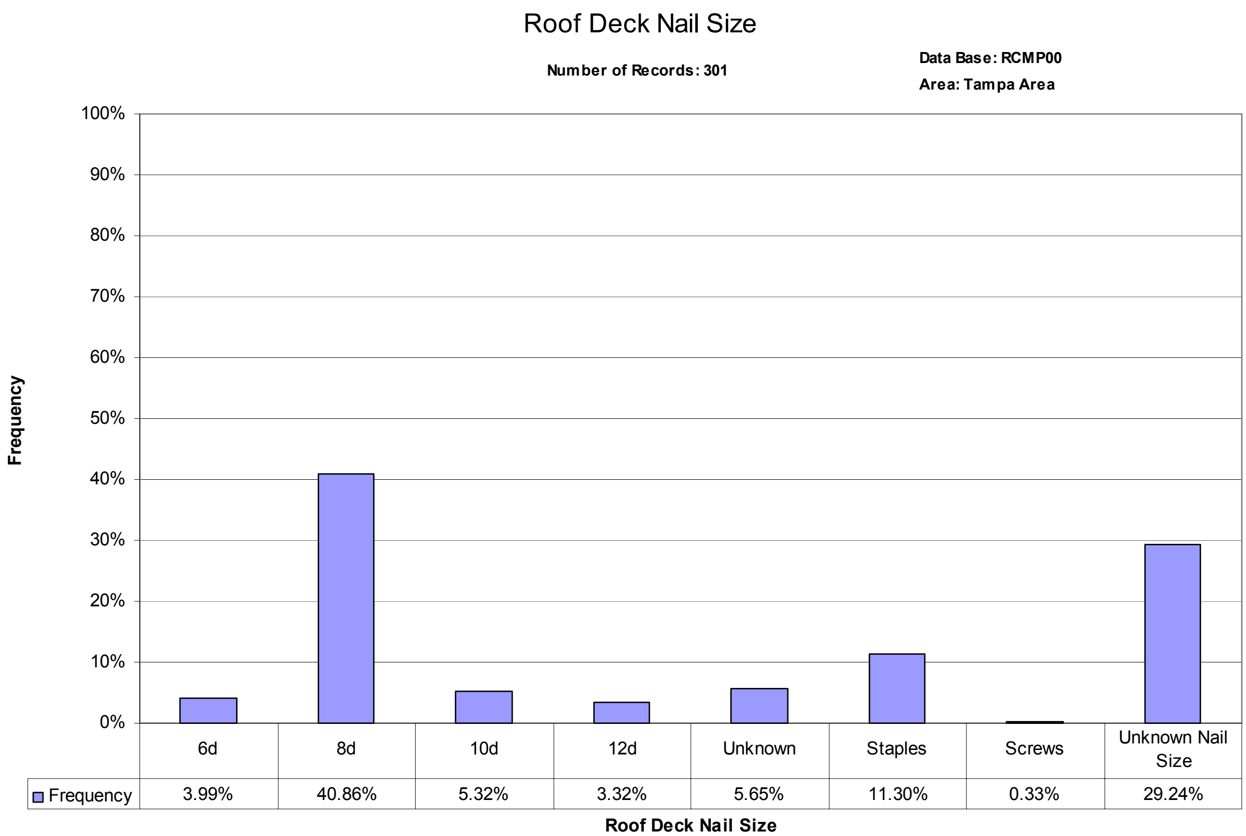
	Shingles	Tile	Built-Up	Metal	Single Ply
Frequency	49.50%	37.87%	5.65%	4.98%	1.99%


Roof Deck Type
Number of Records: 301
Data Base: RCMP00
Area: Tampa Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency
Plywood
OSB
Dimensional Lumber
T&G
Unknown
Series1
39.53%
2.66%
39.20%
1.00%
17.61%
Roof Deck

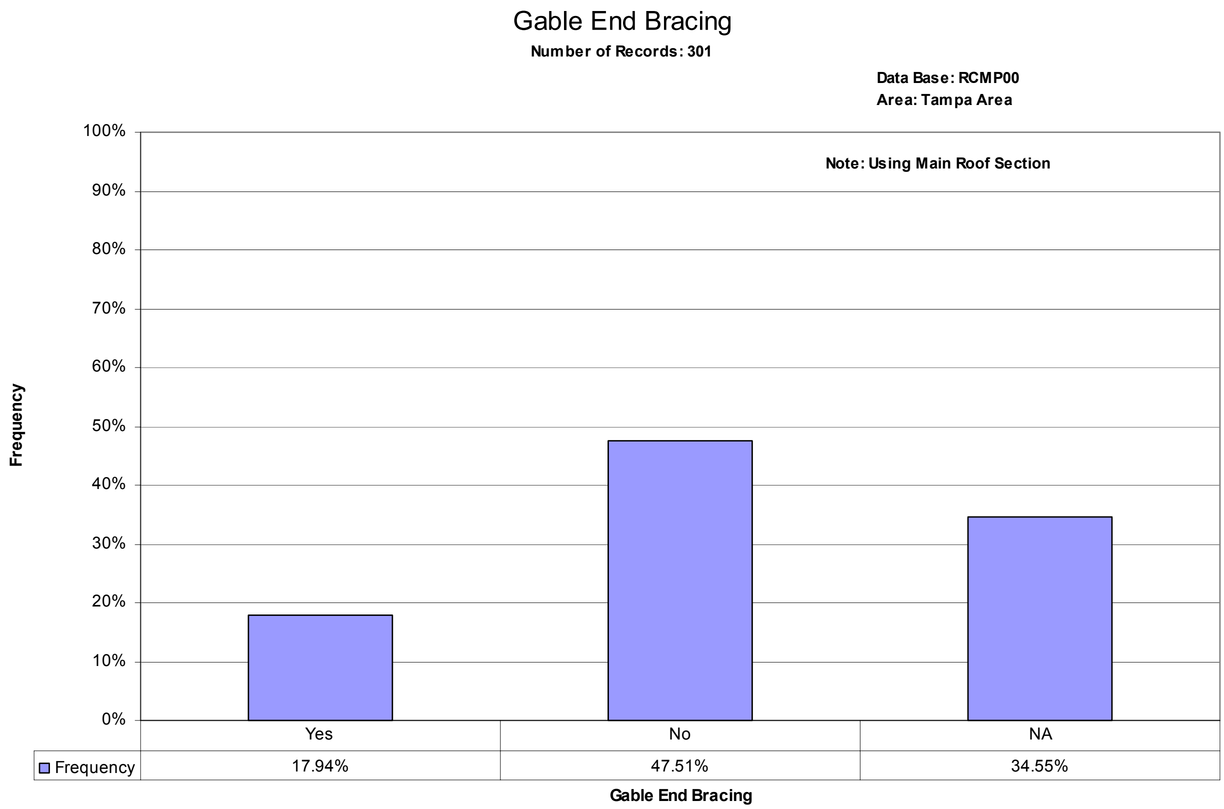

Total Roof Deck Thickness
Number of Records: 301
Data Base: RCMP00
Area: Tampa Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency
greater than 1/4 less than or equal to 1/2
greater than 1/2 less than or equal to 3/4
greater than 3/4 and less than or equal to 1
Frequency
46.18%
46.51%
7.31%
Total Roof Deck Thickness

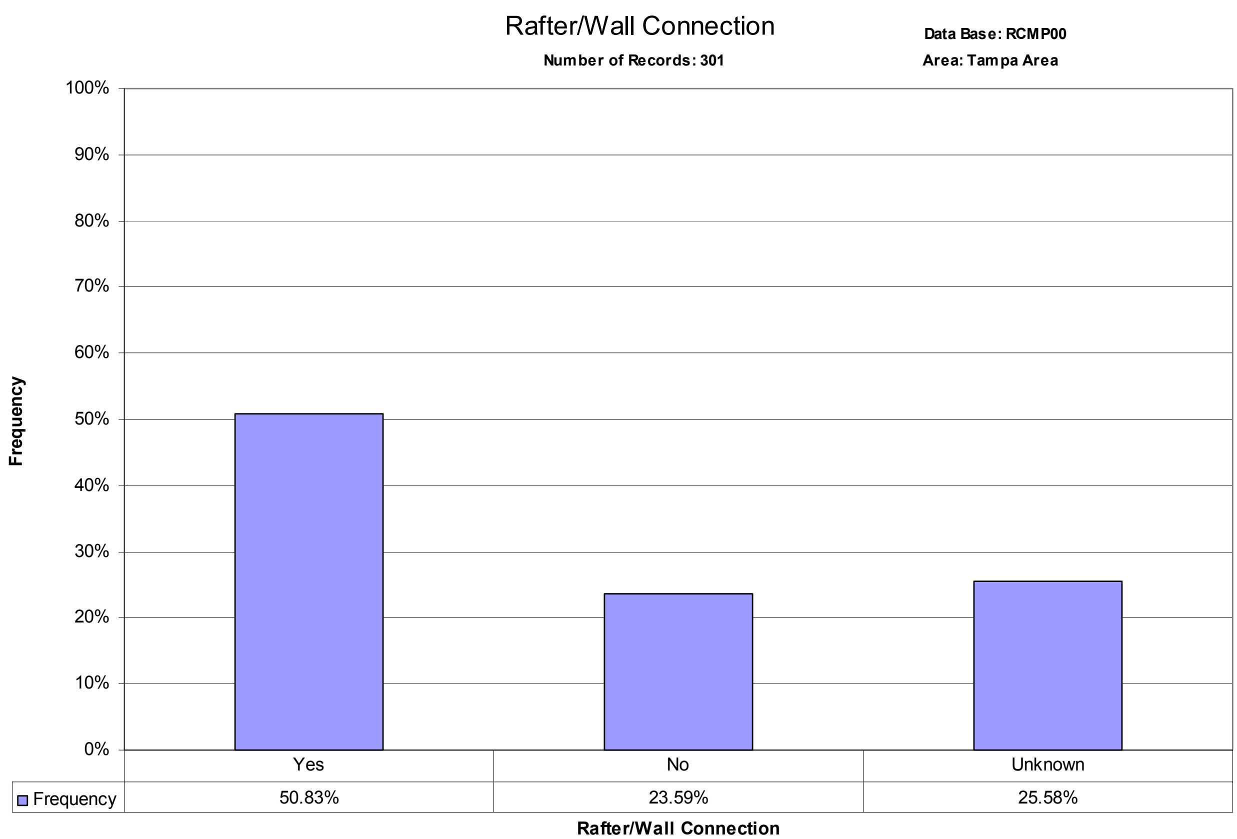


	Nails	Staples	Screws	Unknown
Series1	56.48%	16.94%	0.33%	26.25%



	6d	8d	10d	12d	Unknown	Staples	Screws	Unknown Nail Size
Frequency	3.99%	40.86%	5.32%	3.32%	5.65%	11.30%	0.33%	29.24%


Gable End Bracing
Number of Records: 301
Data Base: RCMP00
Area: Tampa Area
Note: Using Main Roof Section
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No
NA
Frequency
17.94%
47.51%
34.55%
Gable End Bracing


Rafter/Wall Connection
Number of Records: 301
Data Base: RCMP00
Area: Tampa Area
Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No
Unknown
Frequency
50.83%
23.59%
25.58%
Rafter/Wall Connection

APPENDIX H:

YEAR BUILT TAX RECORD DATA

APPENDIX H: YEAR BUILT TAX RECORD DATA

This appendix contains analysis of the Florida Department of Revenue tax records. We obtained Record Layout DR-590 in September 2001 and the data represents the preliminary tax assessment roll for the year 2001. The data was extracted with a Use Code = 01, representing single-family residential occupancies. The "Year Built/Improved" column corresponds to Field 17, "Effective or actual year built of major improvement." We binned the year built information into 5-year bins except for year built prior to 1940, which was summed into a single bin. The total number for each county represents the number of single-family residences in that county as estimated from the tax records.

The "Aggregate Building Value" column of data is shown in this appendix is based on county provided data and has been computed from the tax database by subtracting the "Land Value" from the "Total Just Value". This field therefore does not, in general, correspond, to replacement values or insured values and should not be used as a surrogate for insurance company data. It does, however, point out that a calculation of the distribution of business based on frequency vs value may lead to substantially different estimates of average rating factors.

Table H-1. Year Built Tax Record for Alachua County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	421	0.897	7,658,690	0.251	18,192
1941-45	310	0.661	6,857,080	0.224	22,120
1946-50	1,296	2.761	34,238,820	1.121	26,419
1951-55	1,279	2.725	40,681,080	1.332	31,807
1956-60	3,572	7.611	126,780,840	4.151	35,493
1961-65	5,173	11.022	210,135,600	6.880	40,622
1966-70	4,399	9.373	227,264,270	7.440	51,663
1971-75	5,146	10.965	302,671,730	9.909	58,817
1976-80	5,927	12.629	365,264,670	11.958	61,627
1981-85	5,777	12.309	355,485,570	11.638	61,535
1986-90	4,584	9.767	379,071,520	12.410	82,694
1991-95	4,125	8.789	430,756,870	14.103	104,426
1996-2K	4,924	10.492	567,593,390	18.582	115,271
Totals	46,933	100.000	3,054,460,130	100.000	65,081

Table H-2. Year Built Tax Record for Baker County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	235	8.078	5,356,704	4.137	22,794
1941-45	68	2.338	1,247,937	0.964	18,352
1946-50	129	4.435	2,783,244	2.150	21,576
1951-55	105	3.609	2,452,775	1.894	23,360
1956-60	216	7.425	5,759,253	4.448	26,663
1961-65	135	4.641	4,008,130	3.096	29,690
1966-70	143	4.916	4,942,840	3.818	34,565
1971-75	385	13.235	14,853,642	11.473	38,581
1976-80	358	12.307	16,194,870	12.508	45,237
1981-85	198	6.806	10,494,600	8.106	53,003
1986-90	327	11.241	19,426,212	15.004	59,407
1991-95	300	10.313	19,704,673	15.219	65,682
1996-2K	310	10.657	22,246,776	17.183	71,764
Totals	2,909	100.000	129,471,656	100.000	44,507

Table H-3. Year Built Tax Record for Bay County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,616	3.630	32,874,393	1.214	20,343
1941-45	1,431	3.215	31,598,142	1.167	22,081
1946-50	1,717	3.857	47,150,783	1.741	27,461
1951-55	1,843	4.140	57,401,615	2.119	31,146
1956-60	2,993	6.724	100,545,083	3.712	33,593
1961-65	1,906	4.282	75,022,771	2.770	39,361
1966-70	2,194	4.929	102,417,000	3.781	46,680
1971-75	3,647	8.193	202,359,555	7.471	55,487
1976-80	4,516	10.145	268,810,211	9.925	59,524
1981-85	6,690	15.029	395,683,241	14.609	59,145
1986-90	6,057	13.607	428,341,307	15.815	70,718
1991-95	5,191	11.661	459,736,913	16.974	88,564
1996-2K	4,713	10.588	506,551,265	18.702	107,480
Totals	44,514	100.000	2,708,492,279	100.000	60,846

Table H-4. Year Built Tax Record for Bradford County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	501	10.117	9,083,228	4.409	18,130
1941-45	54	1.090	991,285	0.481	18,357
1946-50	383	7.734	7,774,623	3.774	20,299
1951-55	187	3.776	4,041,821	1.962	21,614
1956-60	616	12.439	14,892,284	7.228	24,176
1961-65	426	8.603	12,974,009	6.297	30,455
1966-70	307	6.200	11,749,937	5.703	38,273
1971-75	456	9.208	21,801,691	10.582	47,811
1976-80	657	13.267	34,906,336	16.942	53,130
1981-85	348	7.027	19,725,290	9.574	56,682
1986-90	442	8.926	26,635,974	12.928	60,262
1991-95	280	5.654	19,365,889	9.400	69,164
1996-2K	295	5.957	22,087,413	10.720	74,873
Totals	4,952	100.000	206,029,780	100.000	41,605

Table H-5. Year Built Tax Record for Brevard County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,413	0.976	49,076,050	0.554	34,732
1941-45	282	0.195	10,054,760	0.114	35,655
1946-50	911	0.629	30,361,200	0.343	33,327
1951-55	3,318	2.292	115,303,180	1.303	34,751
1956-60	14,048	9.704	482,507,800	5.451	34,347
1961-65	19,683	13.597	847,502,260	9.575	43,058
1966-70	9,699	6.700	498,197,250	5.629	51,366
1971-75	5,605	3.872	317,864,230	3.591	56,711
1976-80	14,087	9.731	804,248,080	9.087	57,092
1981-85	19,547	13.503	1,093,920,780	12.359	55,964
1986-90	23,268	16.074	1,668,502,560	18.851	71,708
1991-95	16,629	11.487	1,402,106,630	15.841	84,317
1996-2K	16,270	11.239	1,531,361,240	17.302	94,122
Totals	144,760	100.000	8,851,006,020	100.000	61,143

Table H-6. Year Built Tax Record for Broward County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	16,915	5.080	2,470,394,000	10.044	146,048
1941-45	802	0.241	20,093,790	0.082	25,055
1946-50	1,469	0.441	40,250,880	0.164	27,400
1951-55	13,964	4.194	352,865,550	1.435	25,270
1956-60	36,185	10.868	1,027,817,000	4.179	28,405
1961-65	33,818	10.157	1,193,132,320	4.851	35,281
1966-70	28,072	8.431	1,305,228,120	5.307	46,496
1971-75	35,742	10.735	1,904,044,910	7.741	53,272
1976-80	34,131	10.251	2,294,561,770	9.329	67,228
1981-85	25,462	7.647	1,839,559,350	7.479	72,247
1986-90	34,402	10.332	3,194,447,220	12.988	92,856
1991-95	35,521	10.668	4,054,927,230	16.487	114,156
1996-2K	36,473	10.954	4,898,106,380	19.915	134,294
Totals	332,956	100.000	24,595,428,520	100.000	73,870

Table H-7. Year Built Tax Record for Calhoun County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	218	9.053	2,750,844	3.476	12,619
1941-45	78	3.239	1,049,334	1.326	13,453
1946-50	157	6.520	2,624,349	3.316	16,716
1951-55	123	5.108	2,757,282	3.484	22,417
1956-60	221	9.178	4,899,871	6.191	22,171
1961-65	198	8.223	4,986,248	6.300	25,183
1966-70	190	7.890	6,197,094	7.830	32,616
1971-75	240	9.967	8,123,202	10.263	33,847
1976-80	242	10.050	9,196,425	11.619	38,002
1981-85	215	8.929	8,598,774	10.864	39,994
1986-90	238	9.884	11,386,329	14.386	47,842
1991-95	181	7.517	9,640,723	12.181	53,264
1996-2K	107	4.444	6,936,995	8.765	64,832
Totals	2,408	100.000	79,147,470	100.000	32,869

Table H-8. Year Built Tax Record for Charlotte County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	323	0.606	8,452,634	0.201	26,169
1941-45	58	0.109	2,148,764	0.051	37,048
1946-50	184	0.345	5,777,400	0.138	31,399
1951-55	317	0.595	10,826,393	0.258	34,153
1956-60	3,394	6.367	132,106,600	3.147	38,924
1961-65	3,347	6.279	140,656,735	3.351	42,025
1966-70	2,393	4.489	134,903,261	3.214	56,374
1971-75	5,692	10.679	351,329,858	8.370	61,723
1976-80	6,346	11.906	423,369,729	10.086	66,714
1981-85	7,395	13.874	519,096,379	12.367	70,196
1986-90	11,930	22.381	1,065,757,765	25.390	89,334
1991-95	6,546	12.281	700,194,261	16.681	106,965
1996-2K	5,378	10.089	702,951,869	16.747	130,709
Totals	53,303	100.000	4,197,571,648	100.000	78,749

Table H-9. Year Built Tax Record for Citrus County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	298	0.737	5,543,000	0.252	18,601
1941-45	80	0.198	1,381,400	0.063	17,268
1946-50	308	0.762	6,063,700	0.276	19,687
1951-55	300	0.742	7,049,000	0.320	23,497
1956-60	962	2.380	21,946,900	0.997	22,814
1961-65	1,402	3.468	34,971,100	1.589	24,944
1966-70	2,319	5.737	64,070,832	2.912	27,629
1971-75	4,861	12.025	167,081,500	7.594	34,372
1976-80	5,001	12.371	216,645,500	9.847	43,320
1981-85	5,677	14.044	276,606,900	12.572	48,724
1986-90	8,483	20.985	502,045,200	22.818	59,183
1991-95	5,507	13.623	414,699,050	18.848	75,304
1996-2K	5,226	12.928	482,094,242	21.911	92,249
Totals	40,424	100.000	2,200,198,324	100.000	54,428

Table H-10. Year Built Tax Record for Clay County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	167	0.448	2,868,725	0.112	17,178
1941-45	96	0.257	1,489,030	0.058	15,511
1946-50	447	1.198	8,603,062	0.335	19,246
1951-55	387	1.038	8,787,344	0.342	22,706
1956-60	1,169	3.134	34,034,939	1.325	29,115
1961-65	1,844	4.944	68,048,765	2.650	36,903
1966-70	1,898	5.088	87,695,542	3.415	46,204
1971-75	4,135	11.086	231,500,334	9.014	55,986
1976-80	5,200	13.941	327,023,153	12.733	62,889
1981-85	4,659	12.491	307,192,268	11.961	65,935
1986-90	5,486	14.708	398,036,122	15.498	72,555
1991-95	5,117	13.718	432,505,972	16.840	84,523
1996-2K	6,695	17.949	660,509,409	25.718	98,657
Totals	37,300	100.000	2,568,294,665	100.000	68,855

Table H-11. Year Built Tax Record for Collier County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	231	0.452	10,437,905	0.170	45,186
1941-45	29	0.057	1,412,048	0.023	48,691
1946-50	192	0.375	7,432,959	0.121	38,713
1951-55	555	1.085	27,137,079	0.441	48,896
1956-60	1,057	2.067	45,609,943	0.742	43,150
1961-65	1,407	2.752	71,584,817	1.164	50,878
1966-70	2,892	5.656	168,910,017	2.746	58,406
1971-75	3,630	7.099	230,208,214	3.743	63,418
1976-80	5,635	11.020	400,197,222	6.507	71,020
1981-85	5,158	10.088	409,070,145	6.651	79,308
1986-90	8,893	17.392	975,049,284	15.854	109,642
1991-95	8,151	15.941	1,205,279,356	19.597	147,869
1996-2K	13,302	26.015	2,597,948,251	42.241	195,305
Totals	51,132	100.000	6,150,277,240	100.000	120,282

Table H-12. Year Built Tax Record for Columbia County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	844	8.190	14,470,747	2.947	17,145
1941-45	235	2.280	4,200,550	0.855	17,875
1946-50	479	4.648	10,100,731	2.057	21,087
1951-55	410	3.979	9,612,761	1.958	23,446
1956-60	724	7.026	20,182,098	4.110	27,876
1961-65	836	8.113	27,974,351	5.697	33,462
1966-70	611	5.929	25,041,955	5.099	40,985
1971-75	979	9.500	43,107,687	8.778	44,032
1976-80	1,266	12.285	61,665,017	12.557	48,709
1981-85	722	7.006	41,994,212	8.552	58,164
1986-90	891	8.646	54,802,243	11.160	61,506
1991-95	1,100	10.674	77,146,438	15.710	70,133
1996-2K	1,208	11.722	100,772,602	20.521	83,421
Totals	10,305	100.000	491,071,392	100.000	47,654

Table H-13. Year Built Tax Record for Dade County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	15,229	5.001	556,135,746	2.680	36,518
1941-45	4,176	1.371	166,541,966	0.803	39,881
1946-50	29,294	9.619	1,087,570,655	5.242	37,126
1951-55	38,638	12.687	1,594,721,526	7.686	41,273
1956-60	40,070	13.157	1,906,746,374	9.190	47,585
1961-65	21,626	7.101	1,235,486,789	5.955	57,130
1966-70	21,067	6.918	1,416,055,332	6.825	67,217
1971-75	21,014	6.900	1,553,099,186	7.485	73,908
1976-80	20,674	6.789	1,778,391,106	8.571	86,021
1981-85	16,000	5.254	1,519,685,483	7.324	94,980
1986-90	24,114	7.918	2,448,002,508	11.798	101,518
1991-95	32,239	10.586	2,978,988,369	14.357	92,403
1996-2K	20,403	6.700	2,507,238,936	12.084	122,886
Totals	304,544	100.000	20,748,663,976	100.000	68,130

Table H-14. Year Built Tax Record for DeSoto County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	336	6.704	6,558,700	2.699	19,520
1941-45	100	1.995	2,322,886	0.956	23,229
1946-50	286	5.706	8,354,570	3.438	29,212
1951-55	254	5.068	8,054,900	3.315	31,712
1956-60	426	8.500	13,849,274	5.700	32,510
1961-65	467	9.318	16,620,821	6.841	35,591
1966-70	369	7.362	15,952,057	6.565	43,231
1971-75	638	12.729	28,458,548	11.712	44,606
1976-80	524	10.455	27,981,758	11.516	53,400
1981-85	464	9.258	25,022,249	10.298	53,927
1986-90	541	10.794	38,146,539	15.700	70,511
1991-95	318	6.345	24,706,408	10.168	77,693
1996-2K	289	5.766	26,947,404	11.091	93,244
Totals	5,012	100.000	242,976,114	100.000	48,479

Table H-15. Year Built Tax Record for Dixie County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	54	2.295	1,014,986	1.571	18,796
1941-45	8	0.340	106,214	0.164	13,277
1946-50	59	2.507	871,824	1.349	14,777
1951-55	40	1.700	1,007,325	1.559	25,183
1956-60	809	34.382	13,349,950	20.662	16,502
1961-65	149	6.332	3,585,748	5.550	24,065
1966-70	133	5.652	3,465,492	5.364	26,056
1971-75	149	6.332	4,228,588	6.545	28,380
1976-80	174	7.395	5,702,337	8.826	32,772
1981-85	151	6.417	5,205,939	8.057	34,476
1986-90	286	12.155	10,889,895	16.855	38,077
1991-95	228	9.690	8,758,152	13.555	38,413
1996-2K	113	4.802	6,424,093	9.943	56,850
Totals	2,353	100.000	64,610,543	100.000	27,459

Table H-16. Year Built Tax Record for Duval County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	18,261	8.785	619,533,342	4.608	33,927
1941-45	6,809	3.276	230,959,219	1.718	33,920
1946-50	13,008	6.258	476,800,680	3.546	36,654
1951-55	17,836	8.580	722,479,232	5.373	40,507
1956-60	23,660	11.382	1,055,310,242	7.848	44,603
1961-65	17,098	8.225	856,405,009	6.369	50,088
1966-70	8,115	3.904	470,392,156	3.498	57,966
1971-75	10,414	5.010	668,883,027	4.975	64,229
1976-80	13,415	6.453	976,117,725	7.260	72,763
1981-85	17,739	8.534	1,283,877,654	9.548	72,376
1986-90	23,508	11.309	1,957,876,011	14.561	83,286
1991-95	19,265	9.268	1,928,888,065	14.345	100,124
1996-2K	18,744	9.017	2,198,512,933	16.351	117,292
Totals	207,872	100.000	13,446,035,295	100.000	64,684

Table H-17. Year Built Tax Record for Escambia County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	4,742	5.689	93,296,920	2.294	19,675
1941-45	2,176	2.611	48,280,050	1.187	22,188
1946-50	3,873	4.647	98,844,160	2.430	25,521
1951-55	6,300	7.559	169,190,880	4.160	26,856
1956-60	9,806	11.765	300,681,730	7.394	30,663
1961-65	6,466	7.758	243,316,160	5.983	37,630
1966-70	5,974	7.168	261,459,250	6.429	43,766
1971-75	8,904	10.683	431,063,850	10.599	48,412
1976-80	6,925	8.309	386,011,070	9.492	55,742
1981-85	7,556	9.066	422,903,770	10.399	55,969
1986-90	6,558	7.868	442,530,510	10.881	67,479
1991-95	6,210	7.451	474,759,400	11.674	76,451
1996-2K	7,857	9.427	694,495,140	17.077	88,392
Totals	83,347	100.000	4,066,832,890	100.000	48,794

Table H-18. Year Built Tax Record for Flagler County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	103	0.513	2,762,371	0.176	26,819
1941-45	47	0.234	1,270,643	0.081	27,035
1946-50	103	0.513	2,625,925	0.167	25,494
1951-55	162	0.807	4,262,347	0.271	26,311
1956-60	221	1.101	6,259,201	0.398	28,322
1961-65	152	0.757	4,139,274	0.263	27,232
1966-70	112	0.558	4,186,666	0.266	37,381
1971-75	936	4.664	40,297,049	2.565	43,052
1976-80	1,974	9.836	112,067,314	7.133	56,772
1981-85	2,221	11.067	138,333,451	8.804	62,284
1986-90	4,962	24.725	381,913,975	24.307	76,968
1991-95	3,577	17.824	346,729,109	22.068	96,933
1996-2K	5,499	27.400	526,331,474	33.499	95,714
Totals	20,069	100.000	1,571,178,799	100.000	78,289

Table H-19. Year Built Tax Record for Franklin County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	550	10.601	11,838,299	3.250	21,524
1941-45	158	3.045	3,518,023	0.966	22,266
1946-50	175	3.373	5,530,984	1.519	31,606
1951-55	151	2.911	5,501,889	1.511	36,436
1956-60	425	8.192	19,039,721	5.227	44,799
1961-65	242	4.665	10,256,184	2.816	42,381
1966-70	525	10.120	17,202,476	4.723	32,767
1971-75	398	7.672	18,919,752	5.194	47,537
1976-80	431	8.308	27,568,763	7.569	63,965
1981-85	684	13.184	60,143,856	16.513	87,930
1986-90	496	9.561	48,152,183	13.220	97,081
1991-95	480	9.252	67,554,353	18.547	140,738
1996-2K	473	9.117	69,001,339	18.945	145,880
Totals	5,188	100.000	364,227,822	100.000	70,206

Table H-20. Year Built Tax Record for Gadsden County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	744	8.139	8,750,363	2.440	11,761
1941-45	287	3.140	4,759,705	1.327	16,584
1946-50	600	6.564	10,722,591	2.990	17,871
1951-55	521	5.700	11,936,968	3.328	22,912
1956-60	921	10.075	25,227,112	7.034	27,391
1961-65	720	7.877	22,004,996	6.135	30,562
1966-70	784	8.577	25,813,478	7.197	32,925
1971-75	898	9.824	32,847,602	9.158	36,579
1976-80	899	9.835	39,447,732	10.999	43,880
1981-85	756	8.270	37,656,548	10.499	49,810
1986-90	815	8.916	48,466,043	13.513	59,468
1991-95	674	7.373	46,868,111	13.068	69,537
1996-2K	522	5.711	44,158,188	12.312	84,594
Totals	9,141	100.000	358,659,437	100.000	39,236

Table H-21. Year Built Tax Record for Gilchrist County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	130	7.554	1,941,938	2.682	14,938
1941-45	26	1.511	467,936	0.646	17,998
1946-50	34	1.976	736,132	1.017	21,651
1951-55	33	1.917	717,831	0.991	21,752
1956-60	106	6.159	2,227,180	3.076	21,011
1961-65	68	3.951	1,764,840	2.437	25,954
1966-70	109	6.334	3,400,999	4.696	31,202
1971-75	182	10.575	7,059,553	9.749	38,789
1976-80	279	16.212	11,229,876	15.507	40,250
1981-85	191	11.098	8,785,891	12.132	45,999
1986-90	187	10.866	9,384,837	12.960	50,186
1991-95	172	9.994	10,583,413	14.615	61,531
1996-2K	204	11.854	14,116,170	19.493	69,197
Totals	1,721	100.000	72,416,596	100.000	42,078

Table H-22. Year Built Tax Record for Glades County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	53	3.725	544,598	0.945	10,275
1941-45	14	0.984	168,909	0.293	12,065
1946-50	46	3.233	729,463	1.266	15,858
1951-55	32	2.249	587,445	1.019	18,358
1956-60	124	8.714	2,555,886	4.435	20,612
1961-65	105	7.379	2,830,082	4.911	26,953
1966-70	127	8.925	3,934,015	6.826	30,976
1971-75	189	13.282	7,104,248	12.327	37,589
1976-80	206	14.476	8,802,497	15.274	42,731
1981-85	175	12.298	8,815,226	15.296	50,373
1986-90	134	9.417	7,209,319	12.509	53,801
1991-95	97	6.817	6,060,052	10.515	62,475
1996-2K	121	8.503	8,290,651	14.385	68,518
Totals	1,423	100.000	57,632,391	100.000	40,501

Table H-23. Year Built Tax Record for Gulf County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	51	1.026	485,809	0.185	9,526
1941-45	37	0.745	510,201	0.194	13,789
1946-50	56	1.127	1,063,205	0.405	18,986
1951-55	94	1.892	2,025,569	0.772	21,549
1956-60	341	6.863	6,313,371	2.405	18,514
1961-65	321	6.460	7,528,186	2.868	23,452
1966-70	519	10.445	13,526,031	5.153	26,062
1971-75	538	10.827	16,594,515	6.322	30,845
1976-80	596	11.994	21,576,931	8.220	36,203
1981-85	697	14.027	41,028,697	15.630	58,865
1986-90	654	13.162	43,753,218	16.668	66,901
1991-95	528	10.626	44,480,416	16.945	84,243
1996-2K	537	10.807	63,613,158	24.234	118,460
Totals	4,969	100.000	262,499,307	100.000	52,827

Table H-24. Year Built Tax Record for Hamilton County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	213	11.372	2,370,902	3.534	11,131
1941-45	124	6.620	2,233,464	3.329	18,012
1946-50	121	6.460	2,498,510	3.724	20,649
1951-55	139	7.421	3,940,301	5.873	28,347
1956-60	138	7.368	4,470,044	6.663	32,392
1961-65	132	7.048	4,834,303	7.206	36,624
1966-70	194	10.358	8,290,174	12.357	42,733
1971-75	195	10.411	7,307,187	10.891	37,473
1976-80	184	9.824	8,168,557	12.175	44,394
1981-85	80	4.271	3,769,188	5.618	47,115
1986-90	127	6.781	6,491,403	9.675	51,113
1991-95	91	4.859	4,591,532	6.844	50,456
1996-2K	135	7.208	8,125,720	12.111	60,191
Totals	1,873	100.000	67,091,285	100.000	35,820

Table H-25. Year Built Tax Record for Hardee County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	261	6.729	3,950,527	2.715	15,136
1941-45	137	3.532	2,566,055	1.763	18,730
1946-50	261	6.729	5,573,147	3.830	21,353
1951-55	214	5.517	5,176,474	3.557	24,189
1956-60	394	10.157	10,265,733	7.054	26,055
1961-65	274	7.064	8,675,919	5.962	31,664
1966-70	354	9.126	12,483,881	8.578	35,265
1971-75	598	15.416	20,555,565	14.124	34,374
1976-80	490	12.632	21,651,101	14.877	44,186
1981-85	283	7.296	14,398,569	9.894	50,878
1986-90	272	7.012	17,055,245	11.719	62,703
1991-95	194	5.001	12,468,935	8.568	64,273
1996-2K	147	3.790	10,710,259	7.359	72,859
Totals	3,879	100.000	145,531,410	100.000	37,518

Table H-26. Year Built Tax Record for Hendry County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	159	3.406	2,588,100	1.179	16,277
1941-45	38	0.814	809,070	0.369	21,291
1946-50	66	1.414	1,734,650	0.790	26,283
1951-55	92	1.971	2,561,050	1.167	27,838
1956-60	226	4.841	7,236,020	3.297	32,018
1961-65	387	8.290	12,964,780	5.908	33,501
1966-70	420	8.997	16,236,000	7.399	38,657
1971-75	564	12.082	26,175,500	11.928	46,410
1976-80	799	17.117	38,099,150	17.362	47,684
1981-85	765	16.388	37,870,470	17.258	49,504
1986-90	491	10.518	29,452,560	13.422	59,985
1991-95	456	9.769	26,462,790	12.059	58,032
1996-2K	205	4.392	17,250,280	7.861	84,148
Totals	4,668	100.000	219,440,420	100.000	47,010

Table H-27. Year Built Tax Record for Hernando County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	85	0.188	1,041,665	0.036	12,255
1941-45	23	0.051	349,966	0.012	15,216
1946-50	182	0.402	3,177,567	0.110	17,459
1951-55	164	0.362	2,872,629	0.100	17,516
1956-60	683	1.509	14,046,147	0.487	20,565
1961-65	881	1.946	21,006,863	0.728	23,844
1966-70	1,760	3.888	52,808,420	1.829	30,005
1971-75	2,590	5.721	94,552,712	3.275	36,507
1976-80	6,188	13.669	265,851,155	9.209	42,962
1981-85	9,646	21.308	522,726,618	18.106	54,191
1986-90	11,966	26.433	828,929,409	28.712	69,274
1991-95	5,930	13.099	552,221,569	19.128	93,123
1996-2K	5,172	11.425	527,420,292	18.269	101,976
Totals	45,270	100.000	2,887,005,012	100.000	63,773

Table H-28. Year Built Tax Record for Highlands County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	225	0.820	1,792,920	0.137	7,969
1941-45	167	0.608	2,234,636	0.171	13,381
1946-50	304	1.107	4,756,312	0.365	15,646
1951-55	512	1.865	9,821,793	0.753	19,183
1956-60	958	3.489	21,927,026	1.681	22,888
1961-65	1,874	6.826	52,668,121	4.038	28,105
1966-70	2,292	8.349	80,062,554	6.138	34,931
1971-75	2,340	8.523	85,568,239	6.561	36,568
1976-80	4,209	15.331	179,119,201	13.733	42,556
1981-85	4,046	14.737	192,063,550	14.725	47,470
1986-90	4,888	17.804	269,892,616	20.693	55,215
1991-95	3,161	11.514	212,193,778	16.269	67,129
1996-2K	2,478	9.026	192,191,935	14.735	77,559
Totals	27,454	100.000	1,304,292,681	100.000	47,508

Table H-29. Year Built Tax Record for Hillsborough County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	3,020	1.233	70,325,809	0.433	23,287
1941-45	688	0.281	18,901,339	0.116	27,473
1946-50	4,013	1.639	105,410,259	0.649	26,267
1951-55	3,343	1.365	95,875,197	0.590	28,679
1956-60	13,580	5.546	408,901,152	2.517	30,111
1961-65	17,241	7.041	595,160,945	3.663	34,520
1966-70	31,422	12.832	1,220,985,662	7.515	38,858
1971-75	28,137	11.490	1,329,745,424	8.184	47,260
1976-80	32,105	13.111	1,883,600,742	11.593	58,670
1981-85	36,377	14.855	2,466,079,622	15.178	67,792
1986-90	26,481	10.814	2,288,253,678	14.084	86,411
1991-95	20,311	8.294	2,244,014,632	13.812	110,483
1996-2K	28,158	11.499	3,520,162,704	21.666	125,015
Totals	244,876	100.000	16,247,417,165	100.000	66,350

Table H-30. Year Built Tax Record for Holmes County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	273	9.532	5,085,026	4.988	18,626
1941-45	110	3.841	1,732,191	1.699	15,747
1946-50	144	5.028	2,911,401	2.856	20,218
1951-55	107	3.736	2,272,978	2.229	21,243
1956-60	147	5.133	3,873,085	3.799	26,348
1961-65	159	5.552	5,153,857	5.055	32,414
1966-70	267	9.323	9,565,420	9.382	35,826
1971-75	377	13.163	13,841,478	13.576	36,715
1976-80	368	12.849	15,381,196	15.086	41,797
1981-85	270	9.427	10,246,118	10.050	37,949
1986-90	255	8.904	10,836,503	10.629	42,496
1991-95	198	6.913	9,673,808	9.488	48,858
1996-2K	189	6.599	11,381,861	11.164	60,221
Totals	2,864	100.000	101,954,922	100.000	35,599

Table H-31. Year Built Tax Record for Indian River County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	898	2.627	23,090,520	0.704	25,713
1941-45	109	0.319	3,637,570	0.111	33,372
1946-50	622	1.820	19,624,320	0.598	31,550
1951-55	1,134	3.318	41,657,350	1.270	36,735
1956-60	2,685	7.856	100,286,090	3.057	37,350
1961-65	1,703	4.983	76,130,150	2.321	44,704
1966-70	1,470	4.301	96,474,140	2.941	65,629
1971-75	2,200	6.437	177,005,670	5.396	80,457
1976-80	3,961	11.589	322,207,440	9.822	81,345
1981-85	4,928	14.419	400,783,160	12.217	81,328
1986-90	5,898	17.257	659,764,030	20.112	111,862
1991-95	3,948	11.551	538,944,610	16.429	136,511
1996-2K	4,622	13.523	820,886,410	25.023	177,604
Totals	34,178	100.000	3,280,491,460	100.000	95,983

Table H-32. Year Built Tax Record for Jackson County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	679	7.020	6,665,600	1.850	9,817
1941-45	210	2.171	2,781,384	0.772	13,245
1946-50	585	6.048	8,078,613	2.242	13,810
1951-55	853	8.819	15,391,857	4.271	18,044
1956-60	1,029	10.639	23,187,334	6.435	22,534
1961-65	893	9.233	25,008,881	6.940	28,005
1966-70	972	10.050	31,399,411	8.714	32,304
1971-75	1,129	11.673	43,761,813	12.144	38,762
1976-80	960	9.926	46,556,463	12.920	48,496
1981-85	619	6.400	31,138,463	8.641	50,304
1986-90	735	7.599	46,743,612	12.972	63,597
1991-95	552	5.707	40,881,940	11.345	74,061
1996-2K	456	4.715	38,751,235	10.754	84,981
Totals	9,672	100.000	360,346,606	100.000	37,257

Table H-33. Year Built Tax Record for Jefferson County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	115	5.968	1,637,537	2.244	14,239
1941-45	61	3.166	1,006,786	1.380	16,505
1946-50	125	6.487	2,631,402	3.606	21,051
1951-55	101	5.241	2,668,677	3.657	26,423
1956-60	199	10.327	5,685,757	7.791	28,572
1961-65	146	7.577	4,613,304	6.321	31,598
1966-70	173	8.978	5,837,443	7.999	33,742
1971-75	222	11.520	8,555,864	11.724	38,540
1976-80	245	12.714	10,362,997	14.200	42,298
1981-85	183	9.497	8,307,621	11.383	45,397
1986-90	114	5.916	6,403,173	8.774	56,168
1991-95	101	5.241	5,783,317	7.925	57,261
1996-2K	142	7.369	9,485,984	12.998	66,803
Totals	1,927	100.000	72,979,862	100.000	37,872

Table H-34. Year Built Tax Record for Lafayette County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	104	13.098	2,074,188	7.562	19,944
1941-45	19	2.393	365,149	1.331	19,218
1946-50	35	4.408	742,320	2.706	21,209
1951-55	38	4.786	974,013	3.551	25,632
1956-60	50	6.297	1,078,018	3.930	21,560
1961-65	32	4.030	838,056	3.055	26,189
1966-70	47	5.919	1,368,786	4.990	29,123
1971-75	77	9.698	2,602,300	9.488	33,796
1976-80	85	10.705	2,955,835	10.777	34,775
1981-85	70	8.816	2,814,416	10.261	40,206
1986-90	78	9.824	3,478,821	12.683	44,600
1991-95	74	9.320	3,580,157	13.053	48,381
1996-2K	85	10.705	4,556,339	16.612	53,604
Totals	794	100.000	27,428,398	100.000	34,545

Table H-35. Year Built Tax Record for Lake County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	3,480	5.947	113,355,967	2.931	32,574
1941-45	385	0.658	10,299,561	0.266	26,752
1946-50	2,038	3.483	65,610,342	1.697	32,193
1951-55	2,714	4.638	92,017,066	2.379	33,905
1956-60	4,085	6.981	144,272,422	3.731	35,318
1961-65	2,725	4.657	99,805,493	2.581	36,626
1966-70	1,513	2.586	66,928,049	1.731	44,235
1971-75	3,205	5.477	162,275,802	4.196	50,632
1976-80	3,756	6.419	224,470,774	5.804	59,763
1981-85	3,831	6.547	233,467,856	6.037	60,942
1986-90	6,197	10.590	427,291,748	11.049	68,951
1991-95	9,973	17.043	786,999,054	20.350	78,913
1996-2K	14,616	24.977	1,440,566,087	37.249	98,561
Totals	58,518	100.000	3,867,360,221	100.000	66,088

Table H-36. Year Built Tax Record for Lee County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,819	1.455	106,249,880	0.971	58,411
1941-45	336	0.269	15,511,590	0.142	46,165
1946-50	1,027	0.822	50,138,190	0.458	48,820
1951-55	2,221	1.777	94,877,420	0.867	42,718
1956-60	6,202	4.962	246,145,450	2.250	39,688
1961-65	7,253	5.802	322,810,560	2.950	44,507
1966-70	7,399	5.919	404,327,770	3.695	54,646
1971-75	10,724	8.579	709,209,490	6.482	66,133
1976-80	14,921	11.937	1,061,513,030	9.701	71,142
1981-85	14,960	11.968	1,128,469,720	10.313	75,432
1986-90	21,174	16.939	1,945,129,730	17.777	91,864
1991-95	16,356	13.085	1,940,644,790	17.736	118,650
1996-2K	20,607	16.486	2,916,787,740	26.657	141,544
Totals	124,999	100.000	10,941,815,360	100.000	87,535

Table H-37. Year Built Tax Record for Leon County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,794	2.978	79,818,568	1.758	44,492
1941-45	637	1.058	29,290,841	0.645	45,982
1946-50	2,254	3.742	91,710,041	2.020	40,688
1951-55	2,769	4.597	128,604,379	2.832	46,444
1956-60	3,859	6.407	183,890,153	4.050	47,652
1961-65	3,528	5.857	187,911,336	4.138	53,263
1966-70	3,066	5.090	208,993,501	4.602	68,165
1971-75	4,971	8.253	354,758,579	7.812	71,366
1976-80	6,326	10.502	462,885,652	10.194	73,172
1981-85	8,257	13.708	531,187,547	11.698	64,332
1986-90	8,618	14.308	763,669,337	16.817	88,613
1991-95	7,832	13.003	786,752,495	17.326	100,454
1996-2K	6,323	10.497	731,512,123	16.109	115,691
Totals	60,234	100.000	4,540,984,552	100.000	75,389

Table H-38. Year Built Tax Record for Levy County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	557	9.282	12,855,025	5.082	23,079
1941-45	68	1.133	1,252,313	0.495	18,416
1946-50	270	4.499	5,513,336	2.180	20,420
1951-55	157	2.616	3,645,499	1.441	23,220
1956-60	366	6.099	10,307,971	4.075	28,164
1961-65	363	6.049	11,837,897	4.680	32,611
1966-70	428	7.132	15,526,928	6.139	36,278
1971-75	730	12.165	29,083,558	11.498	39,840
1976-80	741	12.348	34,825,482	13.768	46,998
1981-85	648	10.798	31,754,672	12.554	49,004
1986-90	567	9.448	30,971,543	12.245	54,624
1991-95	598	9.965	32,018,305	12.659	53,542
1996-2K	508	8.465	33,343,603	13.183	65,637
Totals	6,001	100.000	252,936,132	100.000	42,149

Table H-39. Year Built Tax Record for Liberty County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	100	8.278	1,047,482	2.966	10,475
1941-45	18	1.490	163,115	0.462	9,062
1946-50	78	6.457	1,208,168	3.421	15,489
1951-55	41	3.394	651,404	1.845	15,888
1956-60	171	14.156	3,045,827	8.625	17,812
1961-65	101	8.361	2,470,397	6.995	24,459
1966-70	103	8.526	2,794,533	7.913	27,131
1971-75	98	8.113	3,317,566	9.394	33,853
1976-80	132	10.927	5,048,920	14.297	38,249
1981-85	110	9.106	4,042,473	11.447	36,750
1986-90	98	8.113	3,974,745	11.255	40,559
1991-95	91	7.533	4,346,837	12.309	47,767
1996-2K	67	5.546	3,203,632	9.072	47,815
Totals	1,208	100.000	35,315,099	100.000	29,234

Table H-40. Year Built Tax Record for Madison County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	82	2.745	725,886	0.703	8,852
1941-45	30	1.004	371,671	0.360	12,389
1946-50	56	1.875	739,704	0.716	13,209
1951-55	30	1.004	567,665	0.550	18,922
1956-60	72	2.410	1,177,785	1.141	16,358
1961-65	51	1.707	904,403	0.876	17,733
1966-70	644	21.560	12,339,570	11.951	19,161
1971-75	427	14.295	11,847,249	11.474	27,745
1976-80	203	6.796	6,363,478	6.163	31,347
1981-85	856	28.658	39,472,342	38.229	46,113
1986-90	236	7.901	10,027,765	9.712	42,491
1991-95	153	5.122	7,899,828	7.651	51,633
1996-2K	147	4.921	10,816,116	10.475	73,579
Totals	2,987	100.000	103,253,462	100.000	34,568

Table H-41. Year Built Tax Record for Manatee County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	3,000	4.961	117,119,078	2.337	39,040
1941-45	432	0.714	15,511,186	0.309	35,906
1946-50	2,029	3.356	93,295,200	1.861	45,981
1951-55	3,156	5.219	146,370,877	2.920	46,379
1956-60	6,097	10.083	295,452,963	5.895	48,459
1961-65	3,705	6.127	195,964,347	3.910	52,892
1966-70	2,764	4.571	178,178,605	3.555	64,464
1971-75	5,211	8.618	341,460,279	6.813	65,527
1976-80	5,400	8.930	410,931,195	8.199	76,098
1981-85	5,481	9.064	436,361,731	8.706	79,614
1986-90	6,045	9.997	580,675,336	11.585	96,059
1991-95	6,658	11.011	767,180,163	15.307	115,227
1996-2K	10,489	17.347	1,433,607,077	28.603	136,677
Totals	60,467	100.000	5,012,108,037	100.000	82,890

Table H-42. Year Built Tax Record for Marion County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,708	2.566	49,433,716	1.324	28,942
1941-45	423	0.636	11,018,147	0.295	26,048
1946-50	1,091	1.639	28,416,921	0.761	26,047
1951-55	1,402	2.106	41,651,928	1.116	29,709
1956-60	2,579	3.875	80,743,066	2.163	31,308
1961-65	3,865	5.807	127,703,408	3.421	33,041
1966-70	3,646	5.478	147,150,303	3.942	40,359
1971-75	5,218	7.840	235,267,376	6.303	45,088
1976-80	6,712	10.085	340,850,289	9.131	50,782
1981-85	8,557	12.857	443,532,045	11.882	51,833
1986-90	11,001	16.529	653,610,008	17.510	59,414
1991-95	9,595	14.416	665,363,801	17.825	69,345
1996-2K	10,759	16.165	907,978,020	24.325	84,392
Totals	66,556	100.000	3,732,719,028	100.000	56,084

Table H-43. Year Built Tax Record for Martin County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	269	0.707	9,171,625	0.232	34,095
1941-45	71	0.187	2,080,940	0.053	29,309
1946-50	271	0.712	9,521,660	0.241	35,135
1951-55	412	1.083	13,571,222	0.343	32,940
1956-60	1,292	3.395	47,338,844	1.196	36,640
1961-65	947	2.488	39,057,190	0.987	41,243
1966-70	1,276	3.353	57,148,926	1.444	44,788
1971-75	2,739	7.197	151,972,027	3.839	55,484
1976-80	3,311	8.699	201,922,720	5.101	60,985
1981-85	6,249	16.419	475,514,220	12.013	76,094
1986-90	9,731	25.568	1,103,020,430	27.867	113,351
1991-95	5,965	15.673	891,049,926	22.512	149,380
1996-2K	5,527	14.522	956,826,219	24.173	173,119
Totals	38,060	100.000	3,958,195,949	100.000	103,999

Table H-44. Year Built Tax Record for Monroe County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,437	6.242	187,428,835	5.631	130,431
1941-45	298	1.294	34,550,122	1.038	115,940
1946-50	475	2.063	41,417,767	1.244	87,195
1951-55	875	3.801	69,911,037	2.100	79,898
1956-60	1,944	8.444	169,060,643	5.079	86,965
1961-65	1,645	7.145	168,049,740	5.049	102,158
1966-70	1,406	6.107	173,581,093	5.215	123,457
1971-75	2,176	9.451	272,675,013	8.192	125,310
1976-80	2,108	9.156	293,133,077	8.807	139,057
1981-85	2,452	10.650	341,859,529	10.271	139,421
1986-90	3,943	17.126	629,094,162	18.900	159,547
1991-95	2,161	9.386	436,756,027	13.121	202,108
1996-2K	2,103	9.134	511,037,848	15.353	243,004
Totals	23,023	100.000	3,328,554,893	100.000	144,575

Table H-45. Year Built Tax Record for Nassau County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	515	3.838	11,994,265	1.099	23,290
1941-45	140	1.043	4,000,724	0.366	28,577
1946-50	347	2.586	10,271,193	0.941	29,600
1951-55	376	2.802	12,224,175	1.120	32,511
1956-60	830	6.185	29,259,018	2.680	35,252
1961-65	709	5.283	27,692,852	2.537	39,059
1966-70	583	4.344	27,588,001	2.527	47,321
1971-75	1,042	7.765	59,188,548	5.422	56,803
1976-80	1,021	7.608	68,292,122	6.256	66,887
1981-85	1,187	8.845	97,588,695	8.939	82,215
1986-90	2,102	15.663	185,847,794	17.024	88,415
1991-95	2,028	15.112	218,295,859	19.996	107,641
1996-2K	2,540	18.927	339,458,350	31.094	133,645
Totals	13,420	100.000	1,091,701,596	100.000	81,349

Table H-46. Year Built Tax Record for Okaloosa County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	564	1.087	12,464,742	0.342	22,101
1941-45	364	0.702	8,284,521	0.227	22,760
1946-50	1,171	2.257	32,072,703	0.879	27,389
1951-55	1,874	3.612	62,640,067	1.718	33,426
1956-60	3,245	6.254	125,805,427	3.450	38,769
1961-65	3,927	7.569	182,587,347	5.007	46,495
1966-70	3,316	6.391	186,410,375	5.112	56,215
1971-75	4,281	8.251	264,611,823	7.256	61,811
1976-80	5,188	9.999	343,398,305	9.416	66,191
1981-85	7,559	14.569	470,493,870	12.901	62,243
1986-90	6,953	13.401	515,793,725	14.144	74,183
1991-95	6,771	13.050	664,301,853	18.216	98,110
1996-2K	6,671	12.858	777,975,954	21.333	116,621
Totals	51,884	100.000	3,646,840,712	100.000	70,288

Table H-47. Year Built Tax Record for Okeechobee County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	244	4.143	4,686,894	1.547	19,209
1941-45	19	0.323	346,382	0.114	18,231
1946-50	82	1.392	1,838,640	0.607	22,422
1951-55	88	1.494	2,653,341	0.876	30,152
1956-60	353	5.993	11,703,305	3.864	33,154
1961-65	503	8.540	20,232,173	6.680	40,223
1966-70	431	7.317	17,352,568	5.729	40,261
1971-75	826	14.024	37,321,139	12.321	45,183
1976-80	819	13.905	42,996,067	14.195	52,498
1981-85	835	14.177	44,124,479	14.568	52,844
1986-90	600	10.187	40,335,799	13.317	67,226
1991-95	515	8.744	36,155,815	11.937	70,205
1996-2K	575	9.762	43,150,001	14.246	75,043
Totals	5,890	100.000	302,896,603	100.000	51,426

Table H-48. Year Built Tax Record for Orange County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	3,175	1.500	81,720,651	0.506	25,739
1941-45	1,073	0.507	31,659,305	0.196	29,505
1946-50	4,368	2.064	142,109,981	0.879	32,534
1951-55	9,592	4.531	354,505,614	2.194	36,958
1956-60	22,231	10.502	993,318,780	6.148	44,682
1961-65	14,414	6.809	736,348,911	4.557	51,086
1966-70	13,992	6.610	787,499,440	4.874	56,282
1971-75	14,836	7.009	921,881,666	5.705	62,138
1976-80	16,938	8.002	1,202,505,318	7.442	70,995
1981-85	21,798	10.298	1,618,925,468	10.019	74,269
1986-90	32,139	15.183	2,752,239,634	17.033	85,636
1991-95	27,422	12.955	2,761,647,502	17.091	100,709
1996-2K	29,697	14.030	3,773,681,624	23.355	127,073
Totals	211,675	100.000	16,158,043,894	100.000	76,334

Table H-49. Year Built Tax Record for Osceola County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	799	1.645	25,417,689	0.691	31,812
1941-45	132	0.272	3,796,726	0.103	28,763
1946-50	423	0.871	13,490,940	0.367	31,893
1951-55	416	0.857	14,612,223	0.398	35,126
1956-60	1,168	2.405	39,988,705	1.088	34,237
1961-65	920	1.895	34,821,060	0.947	37,849
1966-70	1,723	3.548	72,980,451	1.985	42,357
1971-75	2,252	4.638	120,320,982	3.273	53,429
1976-80	3,274	6.742	191,517,076	5.210	58,496
1981-85	6,056	12.471	358,834,090	9.762	59,253
1986-90	10,662	21.957	769,332,281	20.929	72,156
1991-95	8,634	17.780	719,424,344	19.571	83,325
1996-2K	12,100	24.918	1,311,422,472	35.676	108,382
Totals	48,559	100.000	3,675,959,039	100.000	75,701

Table H-50. Year Built Tax Record for Palm Beach County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	6,392	3.343	549,510,671	2.851	85,969
1941-45	1,188	0.621	56,896,957	0.295	47,893
1946-50	5,634	2.946	238,961,471	1.240	42,414
1951-55	9,302	4.865	429,782,666	2.229	46,203
1956-60	19,500	10.198	957,532,256	4.967	49,104
1961-65	14,996	7.843	863,532,907	4.480	57,584
1966-70	10,048	5.255	674,308,442	3.498	67,109
1971-75	15,417	8.063	1,012,938,378	5.255	65,703
1976-80	25,285	13.224	1,974,702,610	10.244	78,098
1981-85	22,124	11.571	2,101,685,458	10.902	94,996
1986-90	26,089	13.644	3,454,251,580	17.919	132,403
1991-95	17,245	9.019	2,850,812,964	14.788	165,312
1996-2K	17,990	9.409	4,112,453,098	21.333	228,597
Totals	191,210	100.000	19,277,369,458	100.000	100,818

Table H-51. Year Built Tax Record for Pasco County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,296	1.262	25,291,723	0.435	19,515
1941-45	395	0.385	7,407,753	0.127	18,754
1946-50	1,161	1.130	24,936,583	0.429	21,479
1951-55	1,212	1.180	31,521,521	0.542	26,008
1956-60	3,104	3.022	90,264,154	1.551	29,080
1961-65	4,617	4.496	144,468,365	2.483	31,291
1966-70	10,279	10.009	368,104,337	6.326	35,811
1971-75	17,326	16.870	751,078,202	12.908	43,350
1976-80	18,143	17.666	861,979,277	14.814	47,510
1981-85	11,665	11.358	632,086,929	10.863	54,187
1986-90	11,669	11.362	807,171,378	13.872	69,172
1991-95	8,856	8.623	771,189,647	13.254	87,081
1996-2K	12,977	12.636	1,303,022,512	22.394	100,410
Totals	102,700	100.000	5,818,522,381	100.000	56,656

Table H-52. Year Built Tax Record for Pinellas County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	12,870	5.461	366,217,100	2.804	28,455
1941-45	1,476	0.626	39,929,700	0.306	27,053
1946-50	12,372	5.250	347,843,400	2.663	28,115
1951-55	25,793	10.945	770,352,700	5.898	29,867
1956-60	45,186	19.174	1,598,105,400	12.235	35,367
1961-65	20,299	8.613	858,202,000	6.570	42,278
1966-70	16,165	6.859	796,895,900	6.101	49,298
1971-75	21,484	9.116	1,103,852,900	8.451	51,380
1976-80	22,152	9.400	1,381,719,200	10.578	62,374
1981-85	20,672	8.772	1,433,102,400	10.971	69,326
1986-90	16,577	7.034	1,593,944,900	12.203	96,154
1991-95	11,100	4.710	1,357,581,500	10.393	122,305
1996-2K	9,521	4.040	1,414,341,600	10.828	148,550
Totals	235,667	100.000	13,062,088,700	100.000	55,426

Table H-53. Year Built Tax Record for Polk County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	10,339	8.959	292,560,074	4.621	28,297
1941-45	1,253	1.086	28,456,926	0.449	22,711
1946-50	5,217	4.521	143,567,341	2.267	27,519
1951-55	8,124	7.040	260,306,059	4.111	32,042
1956-60	10,778	9.340	379,409,611	5.992	35,202
1961-65	8,624	7.473	326,405,699	5.155	37,849
1966-70	4,818	4.175	248,462,082	3.924	51,570
1971-75	9,999	8.665	514,999,313	8.134	51,505
1976-80	11,824	10.246	689,758,328	10.894	58,335
1981-85	8,638	7.485	528,135,678	8.341	61,141
1986-90	11,188	9.695	798,131,739	12.605	71,338
1991-95	11,121	9.637	870,128,389	13.742	78,242
1996-2K	13,477	11.679	1,251,351,515	19.763	92,851
Totals	115,400	100.000	6,331,672,754	100.000	54,867

Table H-54. Year Built Tax Record for Putnam County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,392	9.139	29,560,399	4.643	21,236
1941-45	325	2.134	6,519,524	1.024	20,060
1946-50	812	5.331	16,873,919	2.650	20,781
1951-55	1,094	7.183	25,189,434	3.956	23,025
1956-60	1,382	9.074	35,259,615	5.538	25,513
1961-65	1,203	7.898	38,594,291	6.062	32,082
1966-70	1,180	7.747	43,167,006	6.780	36,582
1971-75	1,526	10.019	61,778,106	9.703	40,484
1976-80	1,800	11.818	88,982,687	13.976	49,435
1981-85	1,420	9.323	79,833,846	12.539	56,221
1986-90	1,490	9.783	92,049,904	14.458	61,778
1991-95	898	5.896	62,343,879	9.792	69,425
1996-2K	709	4.655	56,528,023	8.879	79,729
Totals	15,231	100.000	636,680,633	100.000	41,802

Table H-55. Year Built Tax Record for Santa Rosa County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	435	1.234	8,280,314	0.326	19,035
1941-45	186	0.528	4,124,359	0.162	22,174
1946-50	407	1.155	9,620,759	0.378	23,638
1951-55	508	1.441	14,422,745	0.567	28,391
1956-60	2,215	6.284	65,522,386	2.577	29,581
1961-65	1,296	3.677	47,866,944	1.883	36,934
1966-70	1,297	3.679	58,135,862	2.287	44,823
1971-75	2,581	7.322	134,676,954	5.297	52,180
1976-80	3,872	10.984	217,085,979	8.539	56,066
1981-85	3,935	11.163	246,732,010	9.705	62,702
1986-90	4,686	13.294	369,638,635	14.540	78,881
1991-95	6,511	18.471	616,653,977	24.256	94,710
1996-2K	7,321	20.769	749,535,425	29.483	102,382
Totals	35,250	100.000	2,542,296,349	100.000	72,122

Table H-56. Year Built Tax Record for Sarasota County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	2,222	2.219	105,414,451	1.207	47,441
1941-45	472	0.471	19,314,114	0.221	40,920
1946-50	2,209	2.206	103,892,456	1.190	47,031
1951-55	4,728	4.722	214,862,249	2.460	45,445
1956-60	10,064	10.052	453,332,711	5.191	45,045
1961-65	7,083	7.074	358,171,400	4.101	50,568
1966-70	5,953	5.946	361,533,295	4.140	60,731
1971-75	9,307	9.295	580,929,395	6.652	62,419
1976-80	14,392	14.374	1,032,998,493	11.828	71,776
1981-85	10,258	10.245	881,310,946	10.091	85,915
1986-90	11,447	11.433	1,376,243,004	15.759	120,227
1991-95	9,636	9.624	1,394,892,890	15.972	144,758
1996-2K	12,353	12.338	1,850,368,299	21.188	149,791
Totals	100,124	100.000	8,733,263,703	100.000	87,224

Table H-57. Year Built Tax Record for Seminole County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,845	1.790	39,020,742	0.436	21,149
1941-45	375	0.364	11,456,460	0.128	30,551
1946-50	1,048	1.017	37,374,012	0.418	35,662
1951-55	1,846	1.791	72,071,372	0.806	39,042
1956-60	6,401	6.210	287,047,296	3.210	44,844
1961-65	3,271	3.174	172,606,934	1.930	52,769
1966-70	5,847	5.673	400,522,389	4.479	68,500
1971-75	12,661	12.284	882,436,091	9.869	69,697
1976-80	13,525	13.122	1,086,213,947	12.148	80,312
1981-85	15,433	14.973	1,280,585,046	14.322	82,977
1986-90	17,985	17.449	1,748,424,001	19.554	97,216
1991-95	11,071	10.741	1,268,493,513	14.187	114,578
1996-2K	11,763	11.413	1,655,140,214	18.511	140,707
Totals	103,071	100.000	8,941,392,017	100.000	86,750

Table H-58. Year Built Tax Record for St Johns County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	448	1.246	6,302,059	0.167	14,067
1941-45	80	0.222	1,093,201	0.029	13,665
1946-50	301	0.837	5,168,048	0.137	17,170
1951-55	338	0.940	7,306,337	0.193	21,616
1956-60	766	2.130	18,969,364	0.502	24,764
1961-65	912	2.536	29,556,212	0.782	32,408
1966-70	1,563	4.347	63,009,448	1.667	40,313
1971-75	2,139	5.949	110,372,620	2.919	51,600
1976-80	3,872	10.769	247,839,271	6.555	64,008
1981-85	4,367	12.145	339,434,188	8.978	77,727
1986-90	6,440	17.911	659,877,234	17.454	102,465
1991-95	6,219	17.296	929,164,402	24.577	149,407
1996-2K	8,511	23.671	1,362,604,653	36.041	160,099
Totals	35,956	100.000	3,780,697,037	100.000	105,148

Table H-59. Year Built Tax Record for St Lucie County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	1,087	1.795	29,019,044	0.755	26,696
1941-45	191	0.315	5,333,889	0.139	27,926
1946-50	1,242	2.051	33,532,621	0.873	26,999
1951-55	1,762	2.910	52,542,067	1.367	29,820
1956-60	3,162	5.222	107,182,770	2.789	33,897
1961-65	2,123	3.506	82,670,974	2.152	38,941
1966-70	1,685	2.783	78,254,789	2.037	46,442
1971-75	4,669	7.711	226,513,586	5.895	48,514
1976-80	7,199	11.889	377,644,892	9.828	52,458
1981-85	8,988	14.844	501,244,698	13.045	55,768
1986-90	13,247	21.877	969,110,712	25.221	73,157
1991-95	7,909	13.062	671,054,216	17.464	84,847
1996-2K	7,287	12.034	708,296,749	18.434	97,200
Totals	60,551	100.000	3,842,401,007	100.000	63,457

Table H-60. Year Built Tax Record for Sumter County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	580	4.018	9,932,041	1.132	17,124
1941-45	65	0.450	1,043,694	0.119	16,057
1946-50	321	2.224	5,450,123	0.621	16,979
1951-55	260	1.801	5,293,192	0.603	20,358
1956-60	481	3.332	10,211,350	1.163	21,229
1961-65	651	4.510	15,981,793	1.821	24,550
1966-70	469	3.249	13,564,491	1.545	28,922
1971-75	572	3.963	18,418,881	2.098	32,201
1976-80	811	5.619	28,784,468	3.279	35,493
1981-85	886	6.138	30,518,642	3.477	34,445
1986-90	767	5.314	32,748,693	3.731	42,697
1991-95	2,018	13.981	127,636,625	14.541	63,249
1996-2K	6,553	45.400	578,169,011	65.869	88,230
Totals	14,434	100.000	877,753,004	100.000	60,811

Table H-61. Year Built Tax Record for Suwannee County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	548	10.967	14,054,653	6.701	25,647
1941-45	151	3.022	3,687,831	1.758	24,423
1946-50	273	5.463	6,786,530	3.236	24,859
1951-55	290	5.803	7,881,526	3.758	27,178
1956-60	324	6.484	8,709,327	4.152	26,881
1961-65	348	6.964	10,984,294	5.237	31,564
1966-70	294	5.884	11,593,749	5.528	39,435
1971-75	383	7.665	15,923,177	7.592	41,575
1976-80	612	12.247	28,694,098	13.681	46,886
1981-85	398	7.965	19,435,237	9.266	48,832
1986-90	461	9.226	24,500,232	11.681	53,146
1991-95	446	8.925	26,123,458	12.455	58,573
1996-2K	469	9.386	31,367,862	14.955	66,882
Totals	4,997	100.000	209,741,974	100.000	41,974

Table H-62. Year Built Tax Record for Taylor County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	128	2.757	1,182,817	0.690	9,241
1941-45	48	1.034	560,131	0.327	11,669
1946-50	129	2.778	1,612,040	0.940	12,496
1951-55	176	3.791	2,761,634	1.611	15,691
1956-60	313	6.741	5,024,550	2.930	16,053
1961-65	436	9.390	9,051,497	5.279	20,760
1966-70	439	9.455	11,330,713	6.608	25,810
1971-75	627	13.504	20,702,686	12.074	33,019
1976-80	629	13.547	25,899,560	15.105	41,176
1981-85	512	11.027	22,273,540	12.990	43,503
1986-90	565	12.169	29,234,991	17.051	51,743
1991-95	338	7.280	19,707,429	11.494	58,306
1996-2K	303	6.526	22,119,560	12.901	73,002
Totals	4,643	100.000	171,461,148	100.000	36,929

Table H-63. Year Built Tax Record for Union County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	41	3.843	345,110	0.867	8,417
1941-45	10	0.937	66,772	0.168	6,677
1946-50	71	6.654	920,249	2.313	12,961
1951-55	32	2.999	807,090	2.029	25,222
1956-60	99	9.278	1,933,399	4.860	19,529
1961-65	100	9.372	2,483,618	6.242	24,836
1966-70	87	8.154	3,175,891	7.982	36,504
1971-75	135	12.652	4,866,842	12.233	36,051
1976-80	132	12.371	5,296,203	13.312	40,123
1981-85	62	5.811	2,699,079	6.784	43,534
1986-90	83	7.779	3,838,195	9.647	46,243
1991-95	94	8.810	5,499,003	13.821	58,500
1996-2K	121	11.340	7,854,476	19.742	64,913
Totals	1,067	100.000	39,785,927	100.000	37,288

Table H-64. Year Built Tax Record for Volusia County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	5,532	4.240	183,289,618	2.292	33,133
1941-45	1,151	0.882	39,602,894	0.495	34,407
1946-50	4,092	3.136	150,713,858	1.884	36,831
1951-55	7,047	5.401	271,342,969	3.393	38,505
1956-60	12,027	9.218	487,383,528	6.094	40,524
1961-65	8,121	6.224	380,563,567	4.758	46,862
1966-70	6,388	4.896	298,632,209	3.734	46,749
1971-75	9,892	7.581	529,860,667	6.625	53,565
1976-80	15,441	11.834	913,443,827	11.421	59,157
1981-85	14,947	11.455	935,639,701	11.698	62,597
1986-90	21,776	16.689	1,542,096,705	19.280	70,816
1991-95	11,101	8.508	973,495,507	12.171	87,694
1996-2K	12,965	9.936	1,292,166,131	16.156	99,666
Totals	130,480	100.000	7,998,231,181	100.000	61,299

Table H-65. Year Built Tax Record for Wakulla County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	88	1.902	1,225,208	0.472	13,923
1941-45	55	1.189	1,084,490	0.417	19,718
1946-50	263	5.685	5,125,195	1.973	19,487
1951-55	208	4.496	4,796,880	1.847	23,062
1956-60	213	4.604	5,814,210	2.238	27,297
1961-65	111	2.399	3,891,473	1.498	35,058
1966-70	186	4.021	6,614,079	2.546	35,560
1971-75	316	6.831	13,009,021	5.008	41,168
1976-80	479	10.355	21,895,733	8.429	45,711
1981-85	498	10.765	26,728,247	10.289	53,671
1986-90	477	10.311	31,209,726	12.014	65,429
1991-95	668	14.440	47,591,318	18.320	71,244
1996-2K	1,064	23.000	90,789,282	34.949	85,328
Totals	4,626	100.000	259,774,862	100.000	56,155

Table H-66. Year Built Tax Record for Walton County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	310	2.406	3,742,279	0.326	12,072
1941-45	134	1.040	2,318,858	0.202	17,305
1946-50	314	2.438	6,082,391	0.529	19,371
1951-55	325	2.523	7,046,630	0.613	21,682
1956-60	632	4.906	15,105,912	1.314	23,902
1961-65	608	4.720	16,147,323	1.405	26,558
1966-70	645	5.007	23,324,253	2.029	36,162
1971-75	830	6.443	32,557,383	2.832	39,226
1976-80	1,170	9.082	52,100,135	4.533	44,530
1981-85	1,352	10.495	80,760,886	7.026	59,734
1986-90	1,596	12.389	143,369,199	12.473	89,830
1991-95	1,998	15.510	285,474,749	24.836	142,880
1996-2K	2,968	23.040	481,394,466	41.881	162,195
Totals	12,882	100.000	1,149,424,464	100.000	89,227

Table H-67. Year Built Tax Record for Washington County

Year Built/Improved	Number of Single Family Residences	% of Total Number	Aggregate Building Value ($)	% of Total Value	Mean Building Value ($/House)
<=1940	355	8.920	9,738,495	6.484	27,432
1941-45	205	5.151	4,489,844	2.989	21,902
1946-50	278	6.985	6,381,078	4.248	22,954
1951-55	174	4.372	4,187,242	2.788	24,065
1956-60	254	6.382	6,978,368	4.646	27,474
1961-65	242	6.080	7,630,666	5.080	31,532
1966-70	220	5.528	6,777,855	4.513	30,808
1971-75	549	13.794	19,586,476	13.040	35,677
1976-80	467	11.734	19,040,709	12.677	40,772
1981-85	314	7.889	14,428,099	9.606	45,949
1986-90	314	7.889	15,980,021	10.639	50,892
1991-95	305	7.663	15,250,136	10.153	50,000
1996-2K	303	7.613	19,731,812	13.137	65,121
Totals	3,980	100.000	150,200,801	100.000	37,739

APPENDIX I:

BUILDING STOCK DISTRIBUTION BY REGION AND ERA

APPENDIX I: BUILDING STOCK DISTRIBUTION BY REGION AND ERA

I.1 General Construction Practices by Year Built and Region

This analysis focuses on the key variables in Section 3 since we are interested in the frequency of those features that appear in the loss relativity tables. We are interested in estimating how construction practices have varied over time in different parts of Florida. The following discussion and plots indicate some important trends that are key to a "best-estimate" quantification of Florida building stock.

I.1.1 Plywood Roof Decks

One of the key fundamental changes in residential construction was the introduction of plywood in the 1950s. Prior to the introduction of plywood, roof decks were largely constructed of dimensional lumber and tongue and groove boards. This change is significant in that the nail spacing for dimensional lumber and tongue and groove boards is typically 2 nails per board, or about a 4-5″ spacing. Plywood decks are typically nailed with a 12″ spacing overall with 6″ on the edges.

Figure I-1 is a plot of the percentage of RCMP houses inspected in each region with plywood or OSB roof decks versus year built. For example, if there were 10 houses inspected in SE Florida that were built in 1960 and 4 of them had plywood decks, the point plotted is 40%. Figure I-1a for Southeast Florida shows that the transition from board decks to plywood decks occurred between about 1955 and 1970. After 1965 over 50% of the homes have plywood decks and close to 100% since the late 1980s. The fact that plywood decks appear for years prior to the 1950s represents the replacement of the original roof deck with a plywood deck. Similarly, the other locations show a similar transition. The plot for Lee county is based on a small county sample with some of the plotting points representing only one house, so there are a lot of 0 and 100% plotting positions.

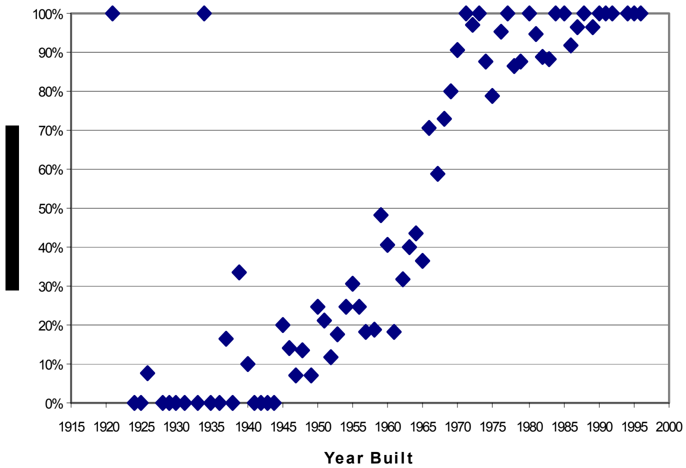
Analysis of an FWUA inspection database of about 5000 homes for plywood roof decks is shown in Fig. I-2. This data also tends to confirm the RCMP data in the trend of plywood roof decks. By about 1965, the FWUA data also shows that over ½ of roof decks were constructed with plywood and the percentage steadily increases to virtually 100%.

A simple construction era model for this feature might simply divide the building stock into pre-1965 and post-1965 eras.

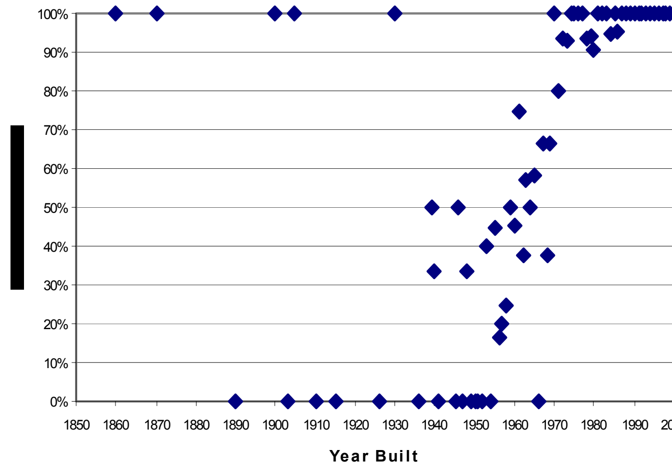
I.1.2 Roof-to-Wall Connectors

As seen from the relativity tables, the roof-to-wall connection is an important element of hurricane loss reduction. Buildings with properly installed metal connections experience roof failures much less frequently as a result of the increased uplift capacity of hurricane straps over toe-nailed connections. Hence, to the extent that there are distinct differences in building stock frequency of roof-to-wall connections, this characteristic will be an important attribute in the characterization of the building stock distribution for single family residences.

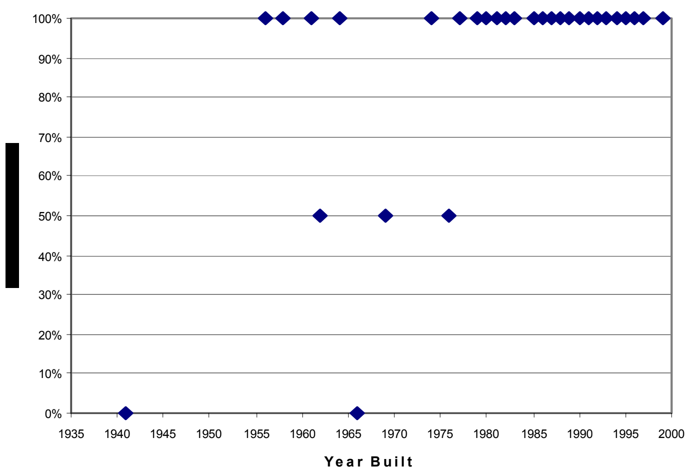
Hurricane straps have been used in South Florida since the 1950s. For masonry wall construction, a metal connection, such as a plumbing strap, has also been used prior to the 1950s. The RCMP data shows a strong transition from toe-nailed connections to metal connectors beginning in the 1950s for all four areas, as shown in Fig. I-3. By 1965-1970, the vast majority of the homes in these coastal areas were being built with metal connectors to hold the roof to the wall. Similarly the FWUA



(a) South Florida



(b) Panhandle



(c) Lee County

(d) Tampa Bay Area

Figure I-1. RCMP Data - Plywood/OSB Roof Deck Construction Data versus Year Built

data (Fig. I-4) shows the trend for roof connectors with over 50% of the inspected houses that were built after about 1960 qualifying for their roof strap credit. An important difference in the frequency of straps for wood frame and masonry walls is discussed in Section I.1.6.

I.1.3 Protection of Openings with SFBC Compliant Protection

The introduction of Edition 4 of the SFBC in 1994 required protection of all openings to a new standard for wind-borne debris impact and subsequent pressure cycling loads. There were also other key improvements in the code, among them improved roof deck attachment, roof covering attachment, and load path strengthening. However, the requirement for opening protection with an engineering based test protocol to qualify products was a significant achievement in the United States. As seen from the relativities in Section 3, opening protection is clearly one of the most important techniques to reduce losses. The RCMP inspection procedures did attempt to obtain information on opening protection. Data was collected to determine if each opening was protected and if each glazed opening was

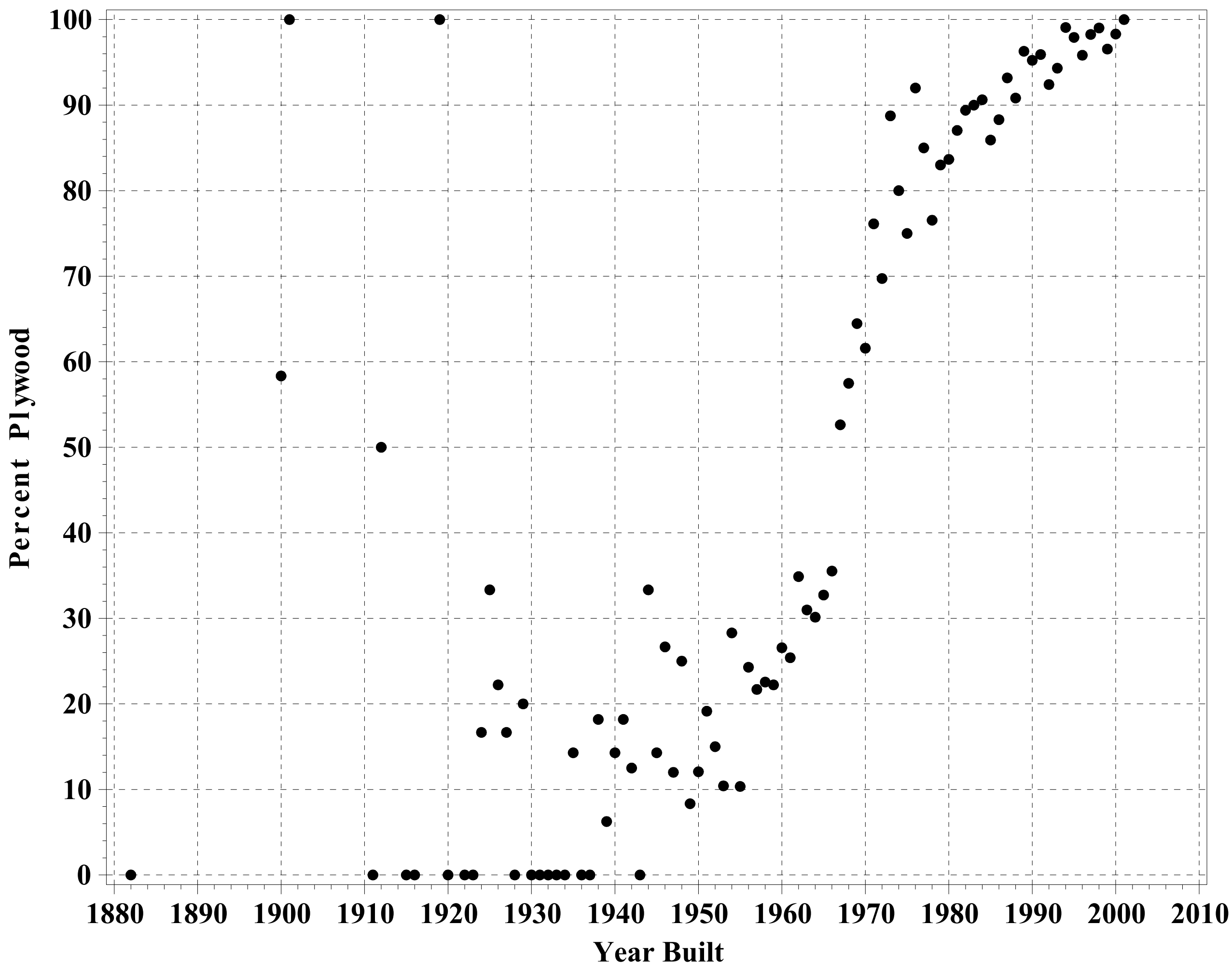
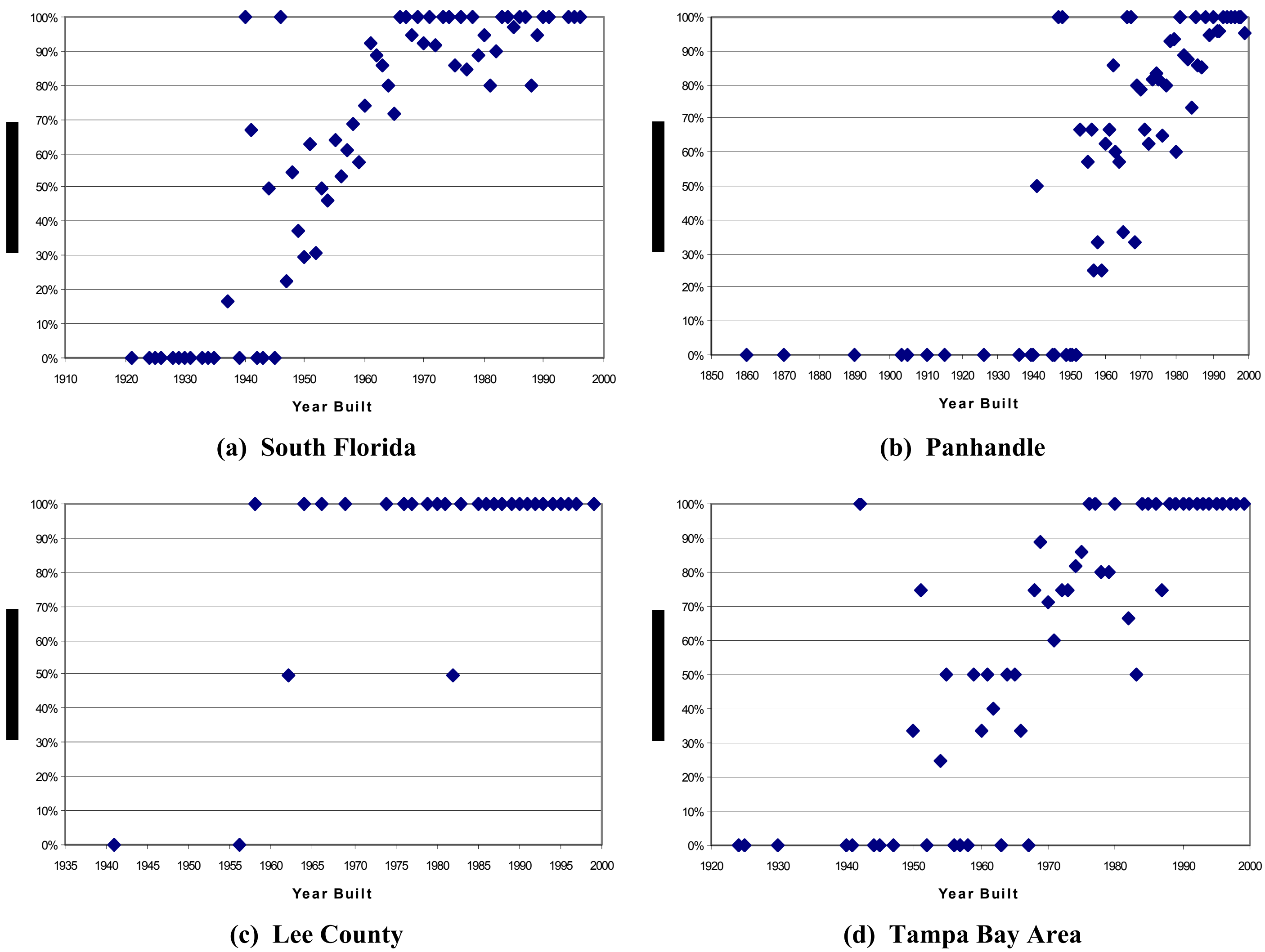


Figure I-2. FWUA Data Trends for Plywood Deck

protected. The protection standard used was the SFBC in SE Florida and SFBC and SSTD 12 in other parts of the state. Because of the difficulty of finding the identification labels on all openings and the fact that the quality of the inspectors varied, this data is useful primarily to observe trends.

Figure I-5 shows the results of this analysis of the RCMP data for all openings (glazing, entry doors, garage doors) protected for missile impact. Note that the collected RCMP data for SE Florida focused on pre-1994 construction and, hence, there is no data for houses built after the introduction of the 1994 Dade code. However, some pre-1994 homes in South Florida have been retrofitted with code-compliant protection. In the Panhandle, we see that some houses built after 1994 are beginning to have opening protection to the new standards. For the Tampa area and Lee County, the inspectors found no homes built with all openings protected to the Dade missile standards.

An analysis similar to Fig I-5 has been done for code compliant protection of glazed openings. Windows and sliding glass doors are the major source of glazed openings in most homes. Figure I-6 shows the results for the RCMP data for protection of glazed openings. As expected, there is a notable difference in the numbers of homes with protected glazing in



(a) South Florida (b) Panhandle

(c) Lee County (d) Tampa Bay Area

Figure I-3. RCMP Data - Roof-to-Wall (Hurricane Clips/Straps) Connections Data versus Year Built

South Florida. This represents the retrofit market in which homeowners in pre-1995 built homes have purchased code compliant protection for windows and sliding glass doors, but have not upgraded or protected the non-glazed doors.

We believe the RCMP data underestimates the frequency of protection of openings because of some of the inspection quality issues prevalent in the early years of the program. It does however show a notable difference in whether or not all openings are protected versus glazed openings. For opening protection, the main conclusion is that the introduction of a standard in 1994 makes an obvious "era" as post-1995 construction, particularly in SE Florida.

I.1.4 Roof Deck Attachment

Roof Deck attachment is another key variable in the loss relativity tables. Building code requirements for roof deck attachment have changed little over the years. In general, the deck attachment has allowed 6d nails for decks with thicknesses less than 15/32″ and 8d nails for thicker decks. Since the pullout resistance differs by a factor of two, there is a

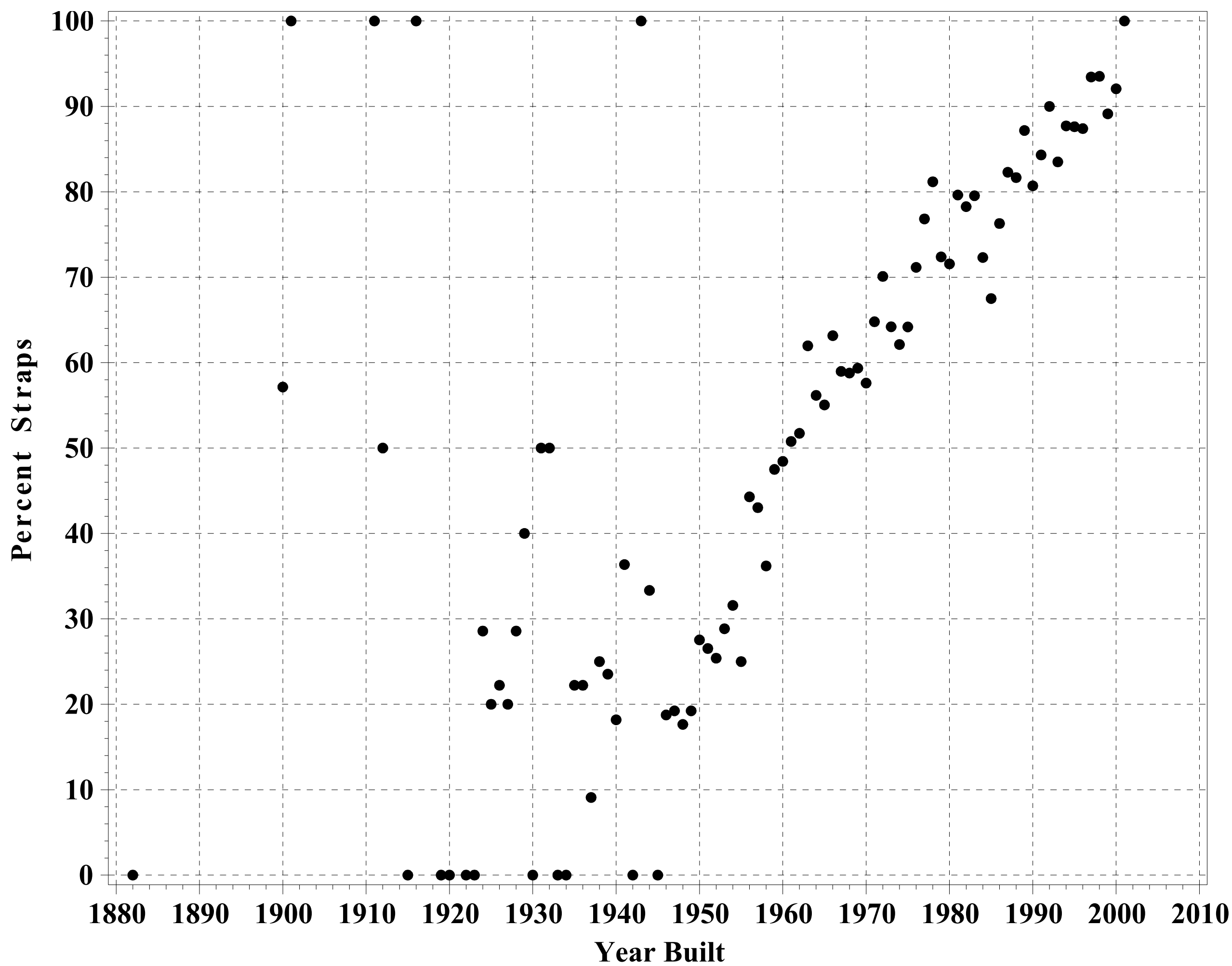


Figure I-4. FWUA Data Trends for Hurricane Clips/Straps

notable loss relativity difference based simply on nail size for the typical 6/12″ nailing pattern. The requirement for improved roof deck attachment appeared in the Dade code in 1994 and in SSTD 10 in 1990.

The RCMP data for roof deck attachment was subject to considerable inspector errors, particularly in the first year of the program. Therefore, this data is useful only to observe trends. The uncorrected data plots of the percentage of plywood roof decks that were nailed with 6d nails are shown in Fig. I-7. The data was divided by nail size equal to or less than 6d and greater than 6d. The percentage of plywood decks nailed with 6d or less nails for all the homes inspected with the same year built are plotted. The points plotted at 0 and 100% generally represent one house inspected with that year built. The South Florida data is biased in that some inspectors called the nail size 8d regardless of its actual size. These errors will be corrected later in this appendix. As expected, there is little trend in this data and as before there were essentially no inspections in South Florida of post-1995 homes built to the new Miami-Dade code.

I.1.5 Roof Shape

Roof shape is a key factor in the loss relativity tables. Hip roofs have much improved aerodynamics over gables. Figure I-8 shows the

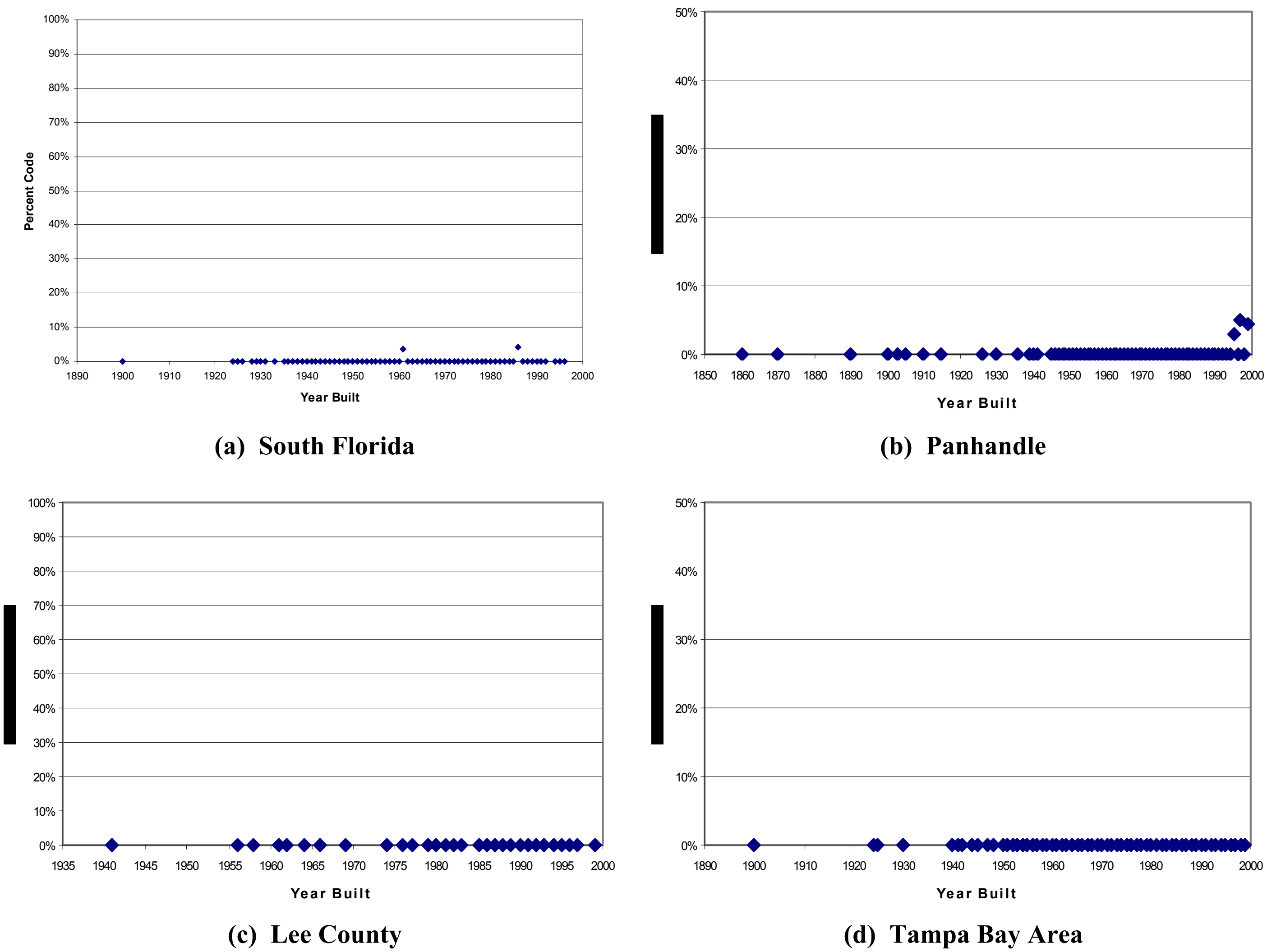


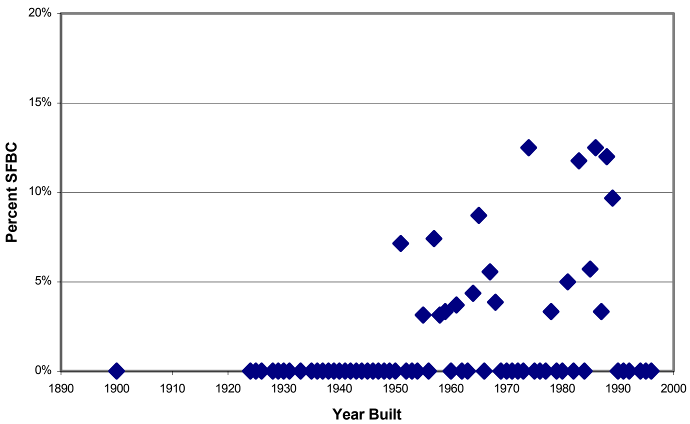
Figure I-5. RCMP Data - SFBC Code Compliant Opening Protection – All Openings Data versus Year Built

RCMP data for percentage hip versus year built. In the analysis of this data, a house is treated as hip only if it is hip or hip and flat. Hips with one or more gables are treated as "other". As expected, these plots show some slight regional differences and a minor time trend. The points plotted at zero and 100% represent only 1 or a few houses inspected with that year built. The FWUA data set is shown in Fig. I-9.

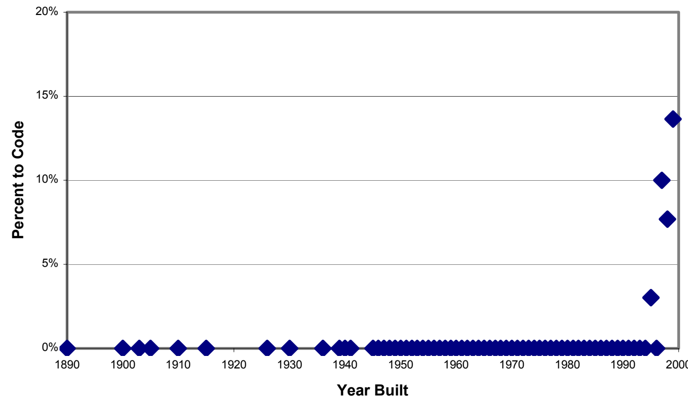
I.1.6 Wall Construction

Per the discussions in Sections 3 and 4, there is a small difference in loss relativity based simply on wall construction. Figure I-10 shows the percentage of homes inspected in the RCMP that have masonry walls. There is a significant difference in the proportion of homes that are masonry versus wood frame in South versus North Florida.

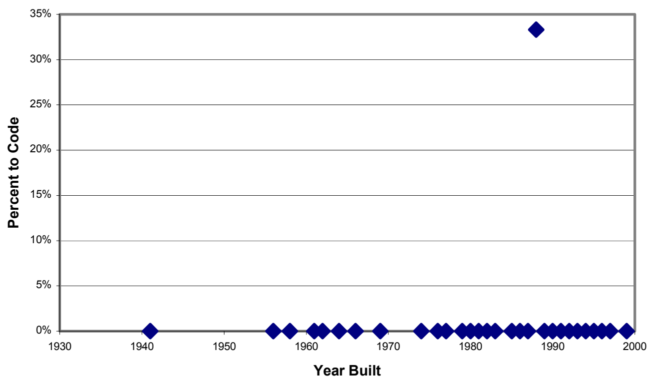
Analysis of the RCMP data shows an important difference in masonry versus wood frame walls. The inspection data confirms that the roof-to-wall connection for masonry walls is more likely to have hurricane straps than for wood frame houses. These results are shown in Fig. I-11 for the RCMP data. The differences



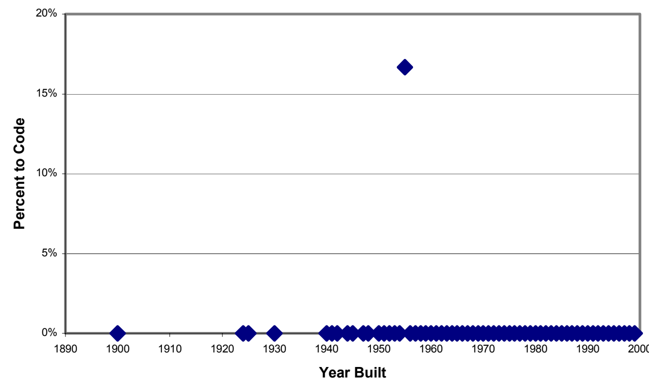
(a) South Florida



(b) Panhandle



(c) Lee County



(d) Tampa Bay Area

Figure I-6. RCMP Data - SFBC Code Compliant Opening Protection – Glazed Openings versus Year Built

are notable in every region except the Panhandle, where the number of masonry homes is very small. Hence, wall construction is an important variable in terms of the fact that masonry walls on average have a higher frequency of hurricane straps than do wood frame walls.

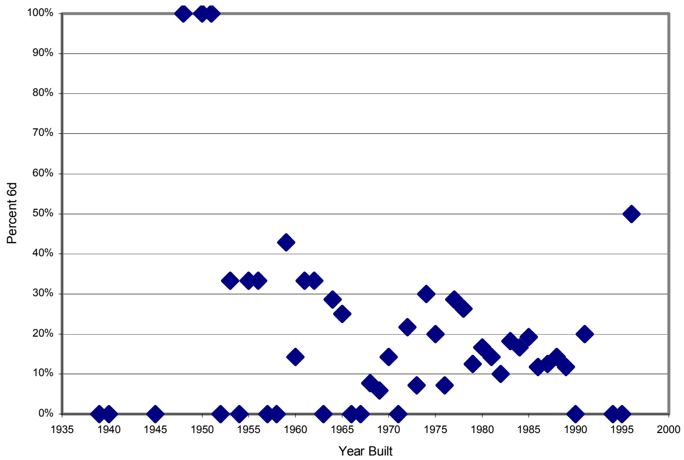
The FWUA plots of masonry versus year building in Fig. I-12 shows little trend.

I.1.7 Other Variables

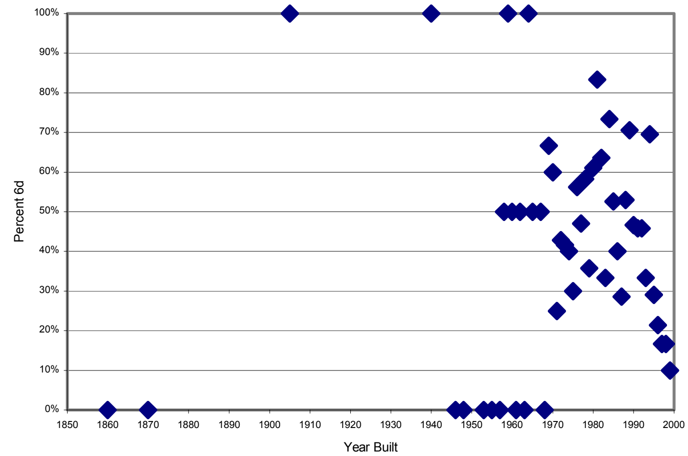
The other main classification variables in the loss relativity tables are roof cover and Secondary Water Resistance (SWR). The RCMP data set does not provide any information on FBC roof covers or SWR.

The fraction of the building stock that currently has FBC roof covers is limited to those homes built after 1995 in counties that had adopted the 1994 SFBC. New construction all over the state should qualify for improved roof cover.

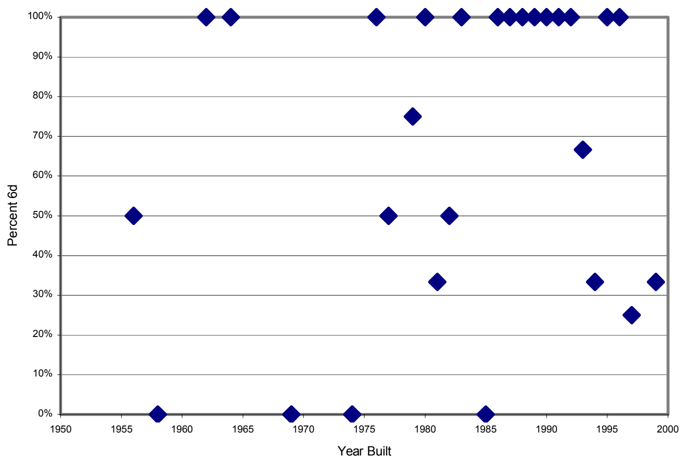
Near zero percent of the building stock have Secondary Water Resistance as it is not a building code requirement, but rather a highly cost effective mitigation technique when done as part of a reroofing of a home.



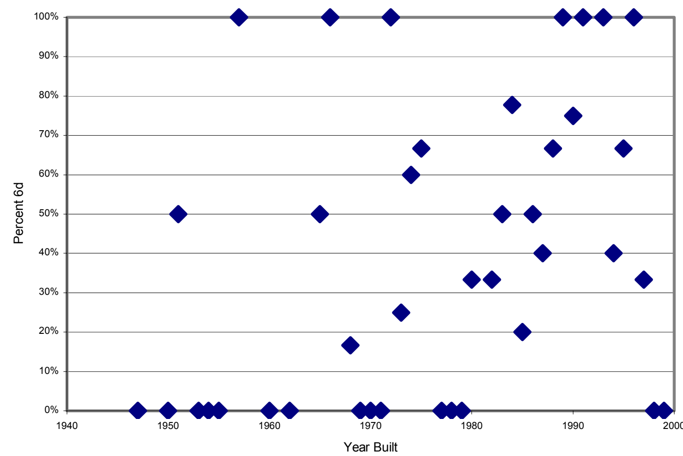
(a) South Florida



(b) Panhandle



(c) Lee County



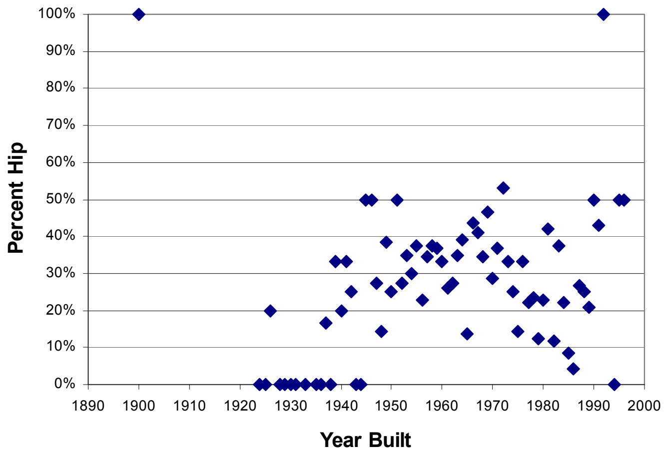
(d) Tampa Bay Area

Figure I-7. RCMP Data - Percent of Plywood Roof Decks Attached with 6d Nails (Uncorrected Data) versus Year Built

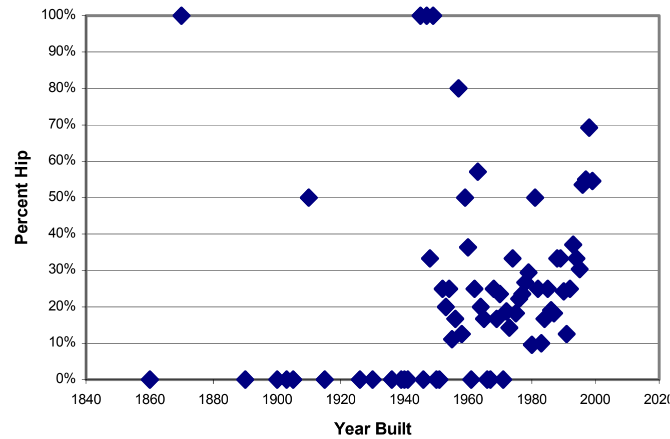
I.2 Recommended Building Stock Regions and Eras

The previous analysis of single variables from the RCMP and FWUA data indicates that a reasonable estimate of the building stock frequencies in the state should consider several different eras of construction practice. The first one corresponds to pre-plywood roof deck and pre-hurricane strap construction typical of buildings prior to the mid-1960s. The second era would cover the period from the mid-1960s until present. In South Florida, a third era is needed to cover the introduction of the 4th edition of the Dade code in 1994, which began to affect houses built in 1995. The third era for South Florida includes homes built in 1995 and later.

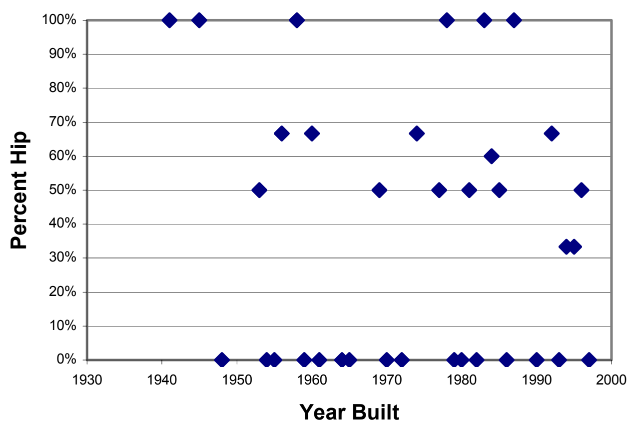
To further evaluate the spatial and time variation of the key rating variables, the FWUA dataset has been analyzed. This analysis has been done using a more sophisticated statistical analysis method since the FWUA data represents more of a continuum of coastal counties as opposed to the distinct pockets of counties represented in the RCMP analysis.



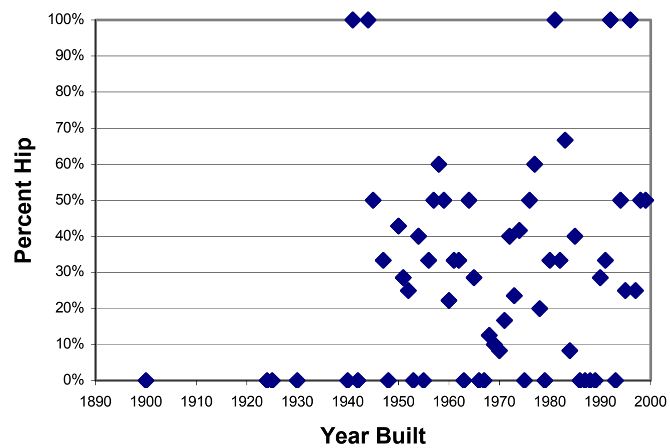
(a) South Florida



(b) Panhandle



(c) Lee County



(d) Tampa Bay Area

Figure I-8. RCMP Data - Percent Hip versus Year Built

Cluster Analysis. To test for building stock subregions and eras within Florida, the CLUSTER procedure of the SAS/STAT [SAS Institute (1992)] module was used to statistically identify clusters based on key building stock variables. The construction parameters considered in this study includes the key ones from the loss relativity table, as described in previous subsections: plywood roof deck, hurricane straps, hip roof shape, masonry walls, and opening protection. Each of these variables is given a weight equal to an approximate average relativity importance, based on Tables 3-2 and 3-5. The subregion means of these variables have standard errors due to house-to-house variation. By using the mean of the parameters for each county, we eliminate some of the inherent house-to-house and year-to-year randomness.

Using SAS, the county five year time blocks were hierarchically clustered with the five construction variables used as coordinates in an n-dimensional space. Hierarchical clusters are organized so that one cluster may be entirely contained within another, but no other kind of overlap between clusters is allowed. For any given number of clusters, all clusters produced, at that level of division are disjoint. This means that each county five-year time block may belong to only one cluster.

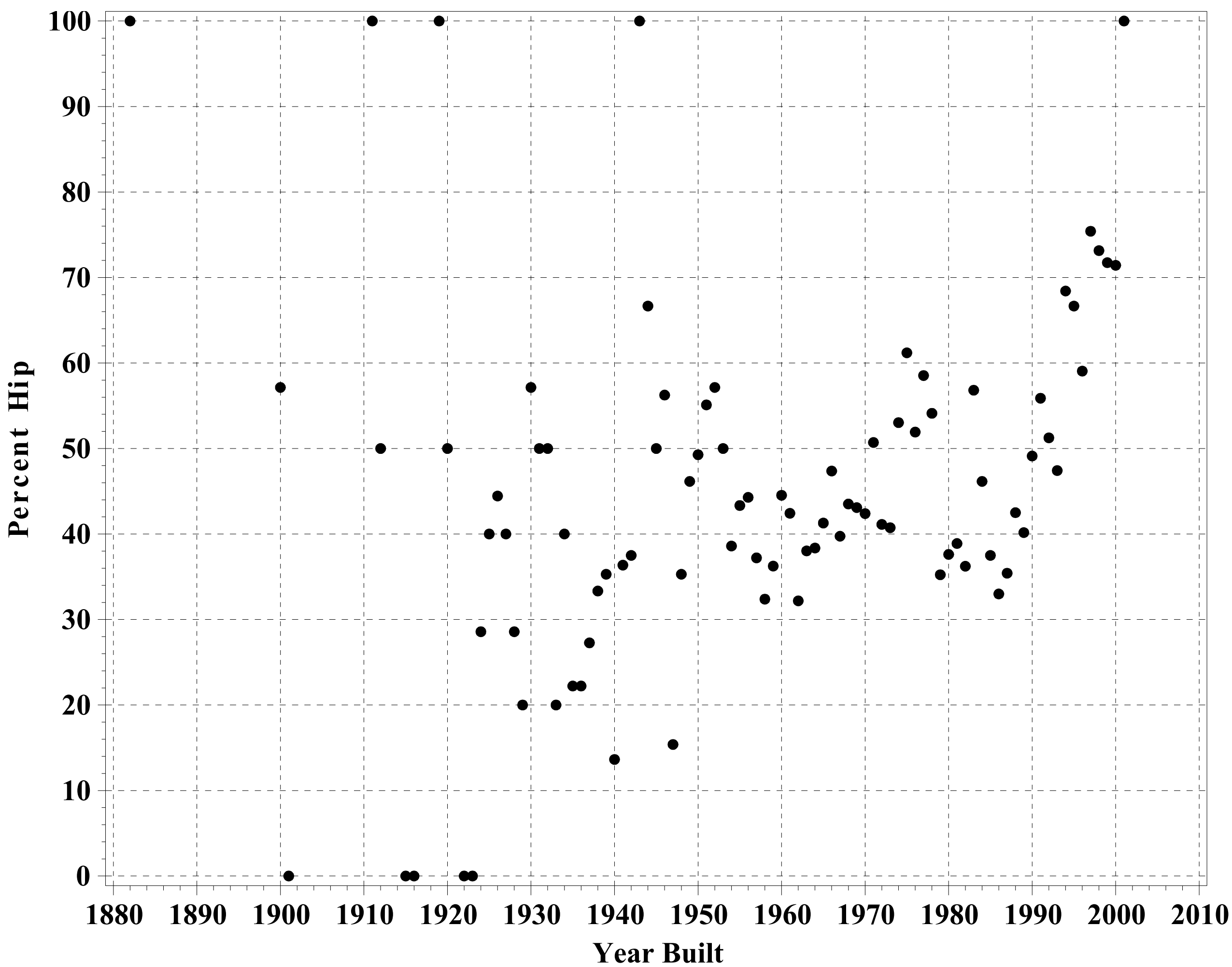
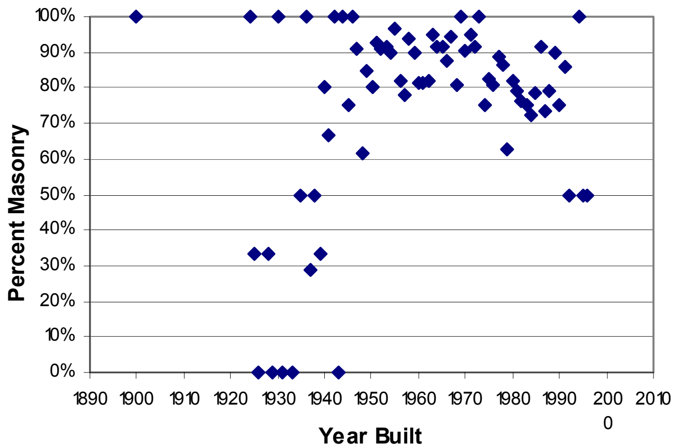


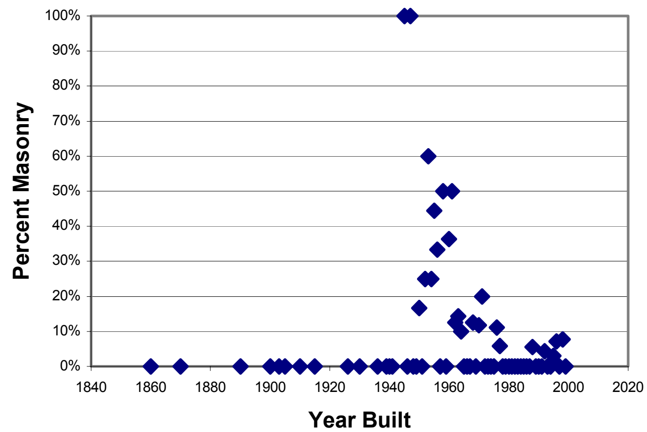
Figure I-9. FWUA Data Trends for Hip

The SAS method chosen is EML, or Maximum-Likelihood hierarchical clustering for mixtures of spherical multivariate normal distributions with equal variances but possibly unequal mixing proportions. EML is similar to Ward's method but removes the bias toward equal-sized clusters. The EML method was derived by W. S. Sarle of the SAS Institute Inc. from the maximum-likelihood formula obtained by Symons (1981) for disjoint clustering. There is no generally satisfactory rule for determining the number of true population clusters for any type of cluster analysis [Everitt (1979); Everitt (1980); Hartigan (1985); Bock (1985)]. A stopping rule has to be chosen based on judgment and data limitations in order to end the progressive division of the region into too many clusters for practical consideration.

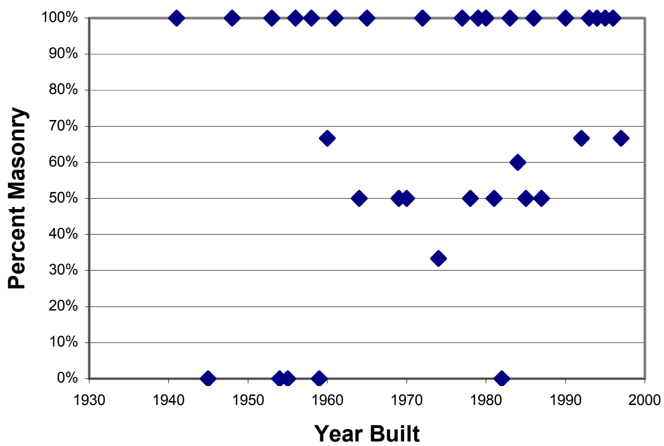
Figure I-13 shows the resulting 2 cluster membership for the FWUA inspected counties. The color of the dot represents the cluster membership, averaged over each five year period of year built. While there is observable randomness in this plot, it shows that the Florida building stock separates by year built. This separation occurs between about 1960 and 1975 for most counties, particularly those with a large sample size in SE Florida. That is, most of the lighter shaded dots occur in more recent years. This trend follows the RCMP data for



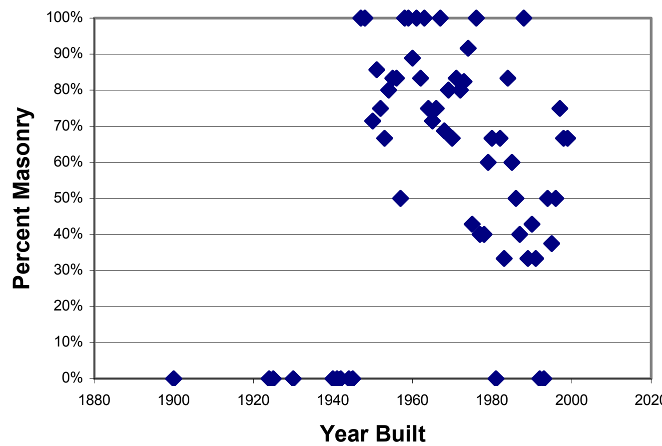
(a) South Florida



(b) Panhandle



(c) Lee County



(d) Tampa Bay Area

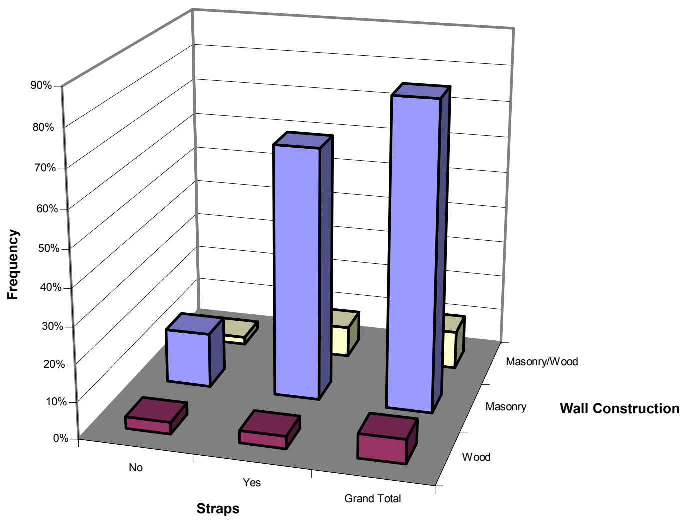
Figure I-10. RCMP Data - Percent Masonry versus Year Built

plywood and hurricane straps, which become predominant in this time period.

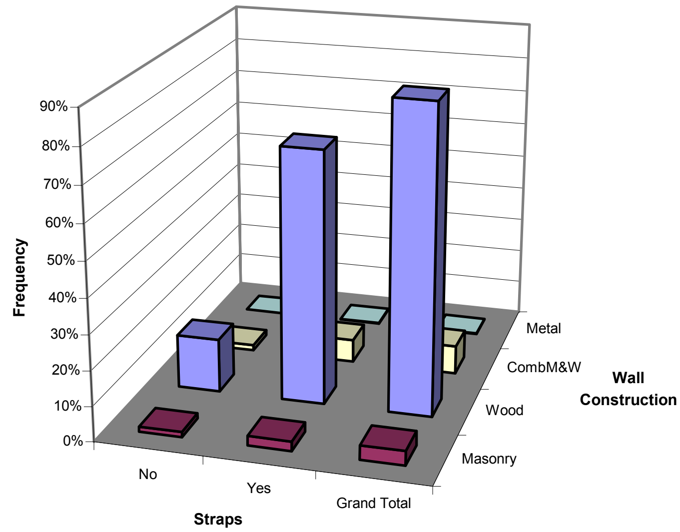
Figure I-14 shows the results for three clusters. The next most important cluster to distinguish itself is the SFBC cluster in Dade and Broward counties, which begins in 1995. The statistical procedure finds these houses as distinct from the rest of the state due to the high percentage of opening protection, straps, and masonry houses.

The 4 cluster results are shown in Fig. I-15. The distinction between North Florida and South Florida appears in this map. Although there clearly is randomness in these plots, some important trends of distinct clusters in time and space are evident. Analyses for 5 or more clusters leads to too many clusters for practical consideration.

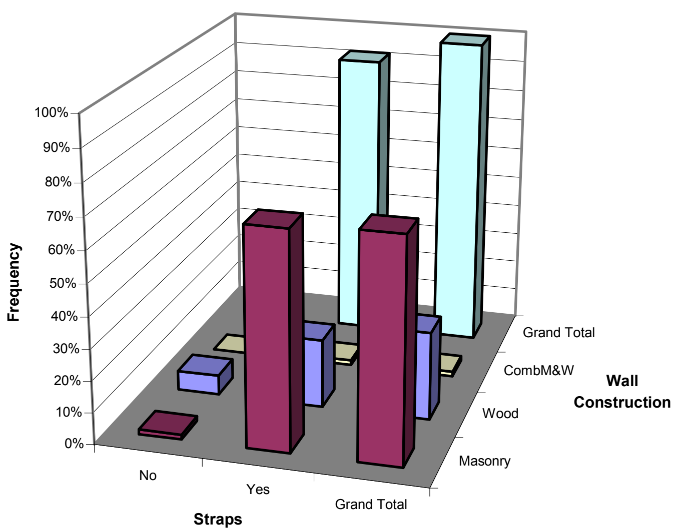
Figure I-16 shows the 4 cluster map for the same analysis except that the data was not binned into 5 year periods. It shows much of the same trends with broader membership in the Southeast Florida cluster.



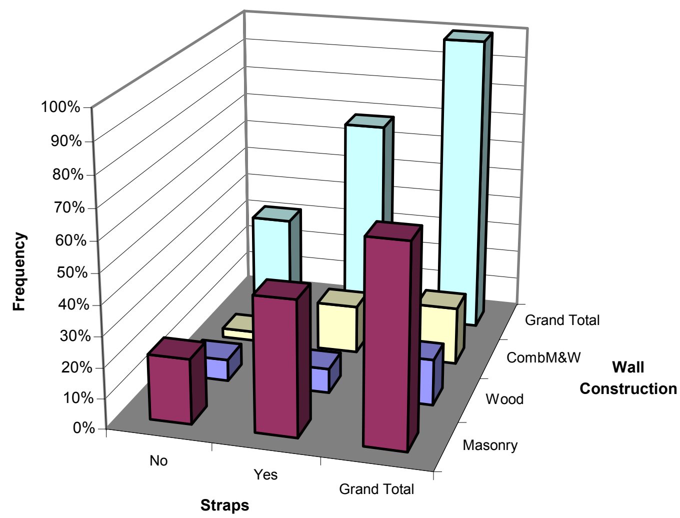
(a) South Florida



(b) Panhandle



(c) Lee County



(d) Tampa Bay Area

Figure I-11. RCMP Data - Wall Construction versus Hurricane Straps

Florida Regions and Construction Eras. Based on the analyses of these data, the map in Figs. I-14 and I-15 supports the subdivision of the state (based on the RCMP data) for purposes of developing a practical building stock model. The state is divided into four basic regions:

I. Southeast Florida

II. South Florida

III. Middle Florida

IV. North Florida.

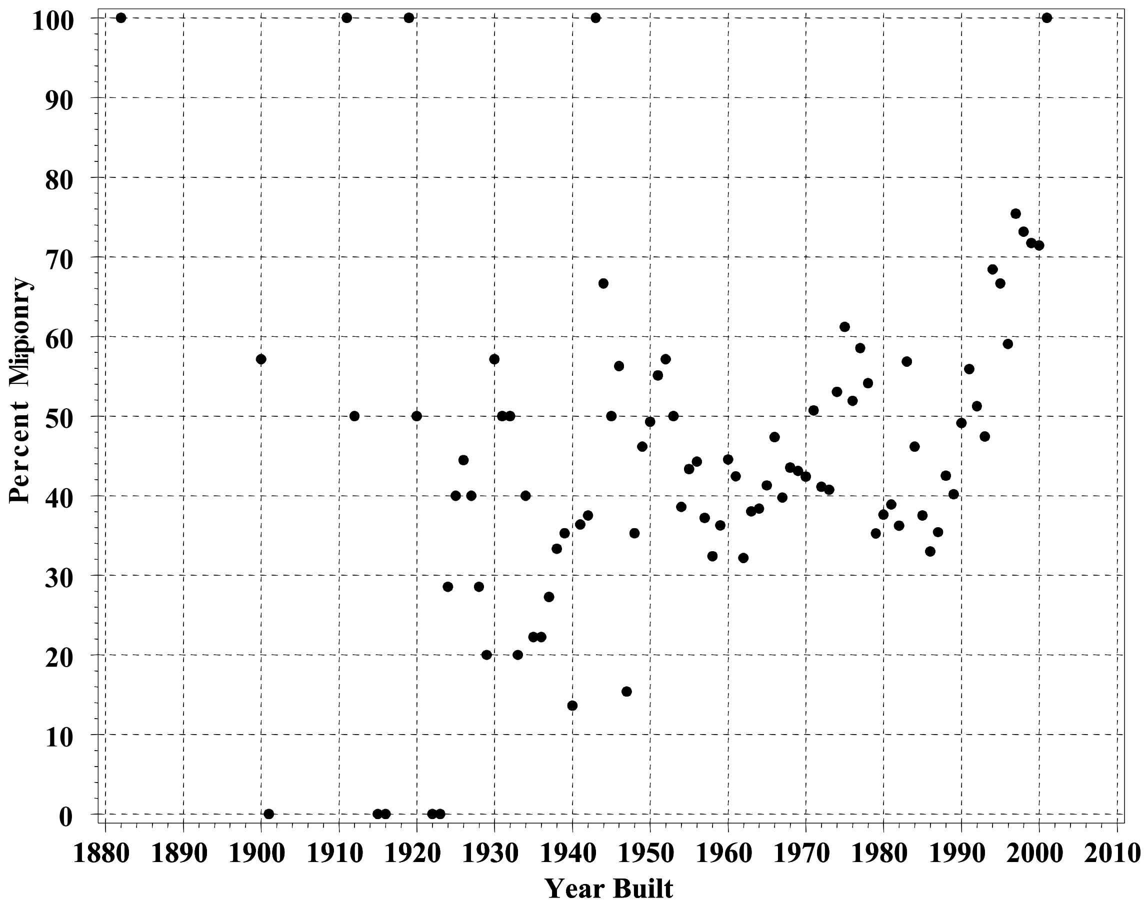


Figure I-12. FWUA Data Trends for Masonry

While this subdivision does not capture notable differences in construction that may exist from county to county, it does treat many of the main trends in Florida construction practices. More in-depth analyses is possible once more data is obtained.

Year built is used to subdivide these regions into two main eras with a third for SE Florida corresponding to the 1994 edition of the SFBC. Table I-1 summarizes these results.

These regions are depicted in Fig. I-17. Region I includes Palm Beach, Broward, Miami-Dade, and Monroe counties. Region II includes the counties listed in Table I-2. The coastal counties in the region are based on the four cluster maps and the interior counties were assigned to this cluster based on proximity. For Region III, Volusia tends to be in the same cluster as the Tampa area and the interior counties were assigned based on proximity. For Region IV, North Florida, and Panhandle and Northeast Florida the counties tended to cluster into the same group.

Table I-1. Region Eras of Florida Residential Building Stock

Region	Year Built Eras
I. Southeast Florida	<1965, 1966-1994, ≥1995
II. South Florida	≤1965, >1966
III. Middle Florida	≤1965, >1966
IV. North Florida	≤1965, >1966

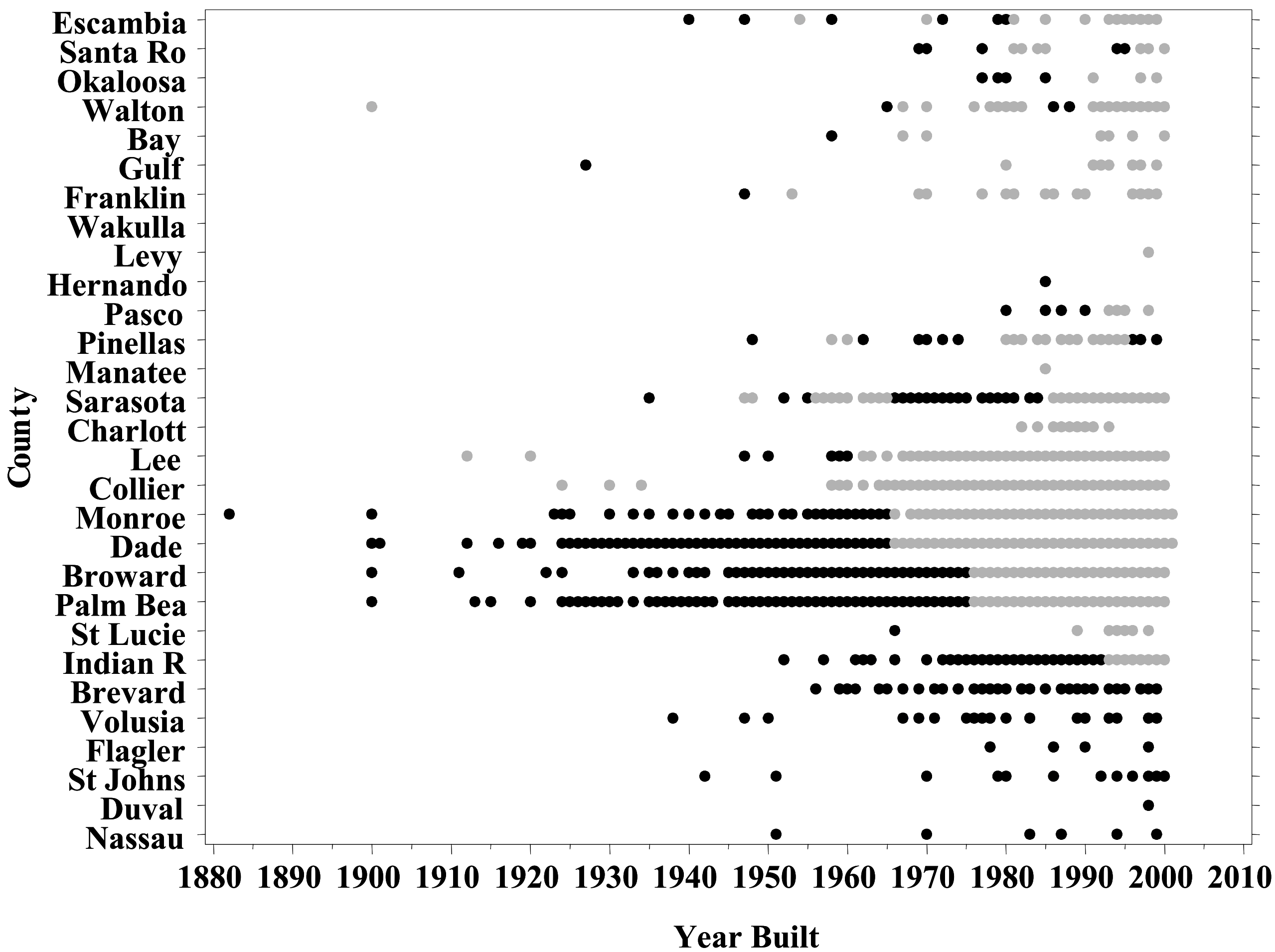


Figure I-13. Two Cluster Map by County and Five Year Time Block – FWUA Data

These definitions of regions are clearly limited by the available data. The lack of data for many counties makes the interior boundaries arbitrary. As more data becomes available, a significantly improved regionalization of building stock will likely emerge.

These four regions are all that can be practically supported by the current data and tend to map reasonably well to the RCMP databases. Regions I, III, and IV have 1,056, 301, and 709 inspections. Regions II has only 65 RCMP inspections in Lee County. Hence, the building stock distribution for Region II requires a blending of the Region I and Region III data.

I.3 Building Stock Distribution

The development of the building stock distributions for existing construction is based on the analysis of the RCMP data. We have analyzed each variable independently and produced the final distributions by combining the marginal distributions. Attempts to introduce correlations were not successfully completed during the schedule of this project. Some of the main problems centered on data quality for the key variables and correlation analysis without correcting the data for obvious inspector errors would only promulgate the inspection errors through false correlations. Therefore, in the absence of additional research

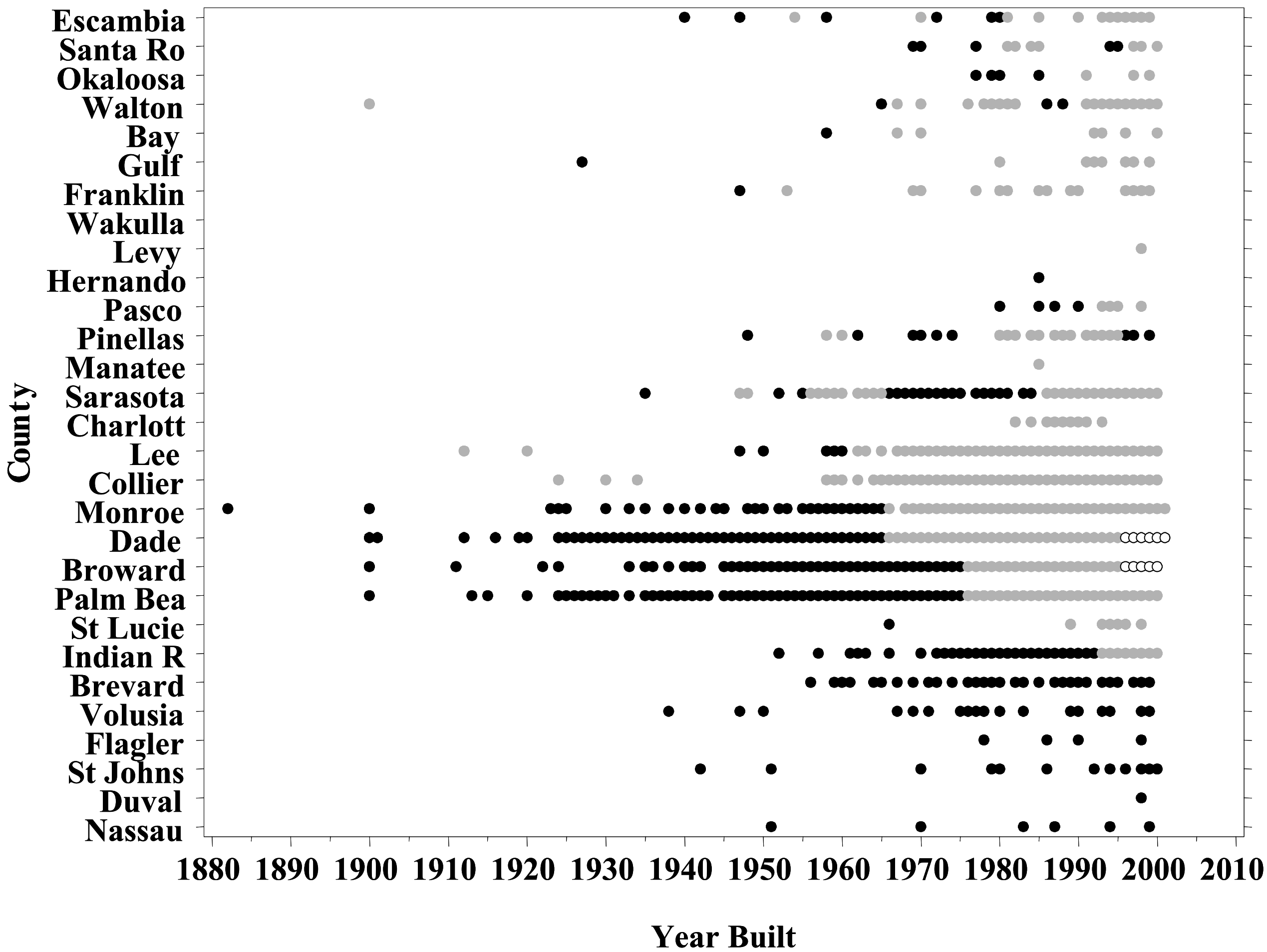


Figure I-14. Three Cluster Map by County and Five Year Time Block – FWUA Data

and improved data, the building stock distributions are estimated assuming independence among the rating variables. This is a simpler approach that also enables users to make adjustments to the marginal distributions and compute updated distributions by direct computation.

Tables I-3 gives the results of the analysis of the RCMP data and the following paragraphs discuss the method of analysis for each variable separately.

I.3.1 Roof Shape

These distributions of roof shape (other and hip) are based on the RCMP inspections. Reinspections of randomly selected RCMP houses showed that the inspectors correctly classified the roof shape for 85-95% of the homes. For the reinspected homes, if the data showed a roof shape classification error, then the corrected roof shape was used in the analysis. No attempt was made to make statistical corrections to the remaining roof shape data since the data quality was judged to be reasonably good. The hip shape classification includes all houses with pure hips as well as houses with hip-flat roofs, where the flat roof is generally a small area over a porch or sunroom.

For Region II, only 8 RCMP inspections were made in Lee County for pre-1966 built houses and the frequency of hip

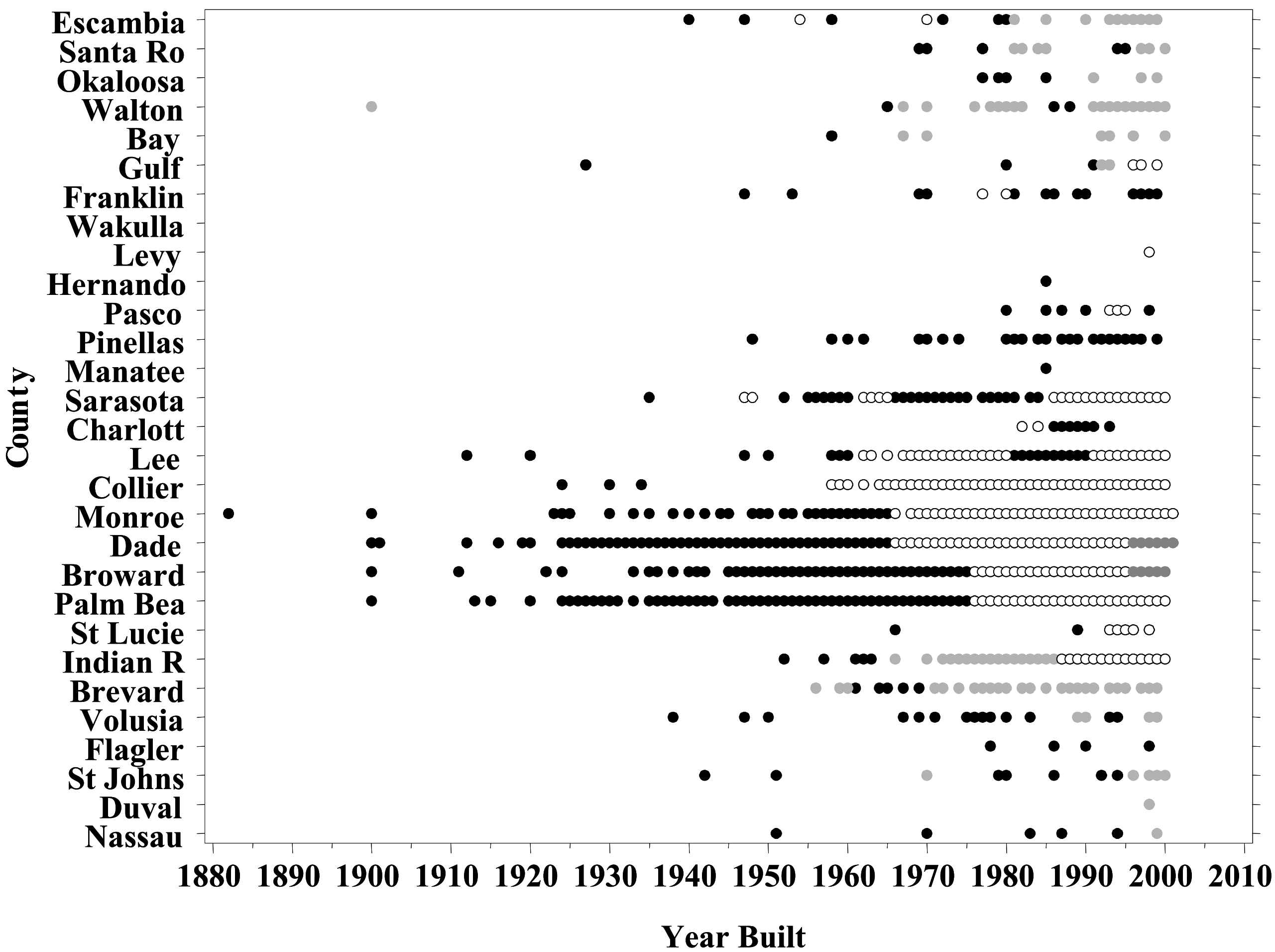


Figure I-15. Four Cluster Map by County and Five Year Time Block – FWUA Data

Table I-2. Counties in Each Building Stock Region

Region	Number of Counties	Counties
I. Southeast Florida	4	Palm Beach, Broward, Miami-Dade, and Monroe
II. South Florida	13	Brevard, Indian River, Saint Lucie, Martin, Okeechobee, Highlands, Desoto, Sarasota, Charlotte, Glades, Lee, Hendry, and Collier
III. Mid Florida	13	Volusia, Lake, Sumter, Hernando, Pasco, Pinellas, Seminole, Orange, Hillsborough, Polk, Osceola, Manatee, and Hardee
IV. North Florida	37	Escambia, Santa Rosa, Okaloosa, Walton, Holmes, Washington, Bay, Jackson, Calhoun, Gulf, Gasden, Liberty, Franklin, Leon, Wakulla, Jefferson, Madison, Taylor, Hamilton, Suwannee, Lafayette, Dixie, Columbia, Oilchrist, Levy, Citrus, Baker, Union, Bradford, Alachua, Marion, Clay, Putnam, Nassau, Duval, Saint Johns, and Flagler

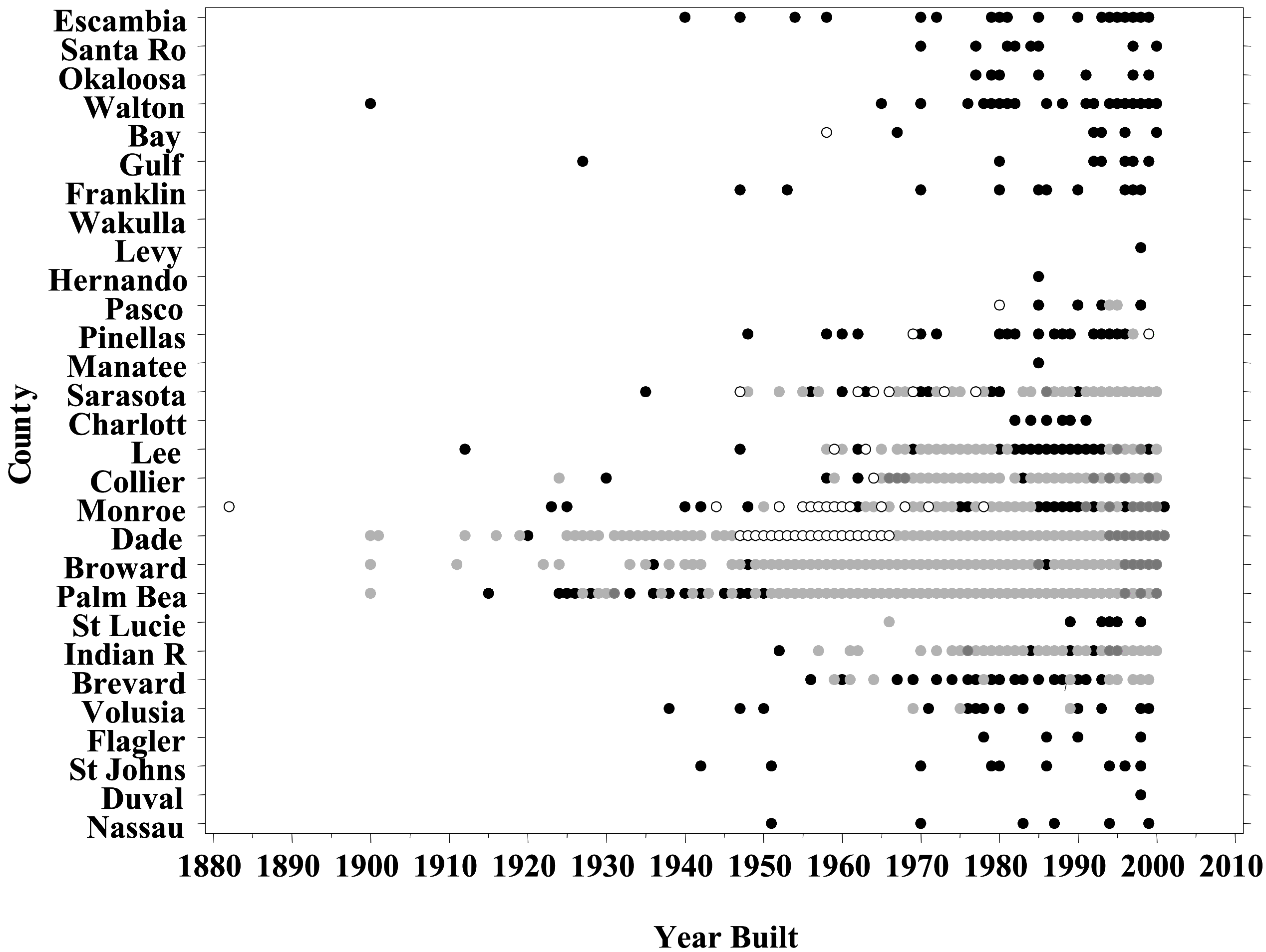


Figure I-16. Four Cluster Map by County and One Year Time Block – FWUA Data

roofs was 12.5%. Due to this very small sample size, this frequency was not judged to be representative and the percent hip frequency for this region and era was set equal to the Region I data.

Table I-3 shows a higher frequency of hips in South Florida, particularly for older construction. Note that if a hip shape house had one gable, then the house was counted as "other" in this analysis.

1.3.2 Roof-Wall Connection

The RCMP data collection on roof-wall connection was accurate about 90% of the time for the Tampa, Lee County, and Panhandle inspections. The inspections in Southeast Florida during the first year of the program were accurate about 70% of the time. Table I-3 gives the estimated frequency distributions of toe-nail, clip, wrap, and double-wrap connections. For Regions II, III, and IV the distributions are based on the RCMP inspections with some slight judgment-based smoothing to reflect the re-inspection data and any zero observed frequencies. The main exception to the direct use of the RCMP data is for the pre-1966 Region II era, which only included a few inspections in Lee County. To estimate these distributions, we simply averaged the Region I and Region III data.

For Region I, due to the lower quality of the RCMP inspection data and the larger number of re-inspections (over 229 homes), the

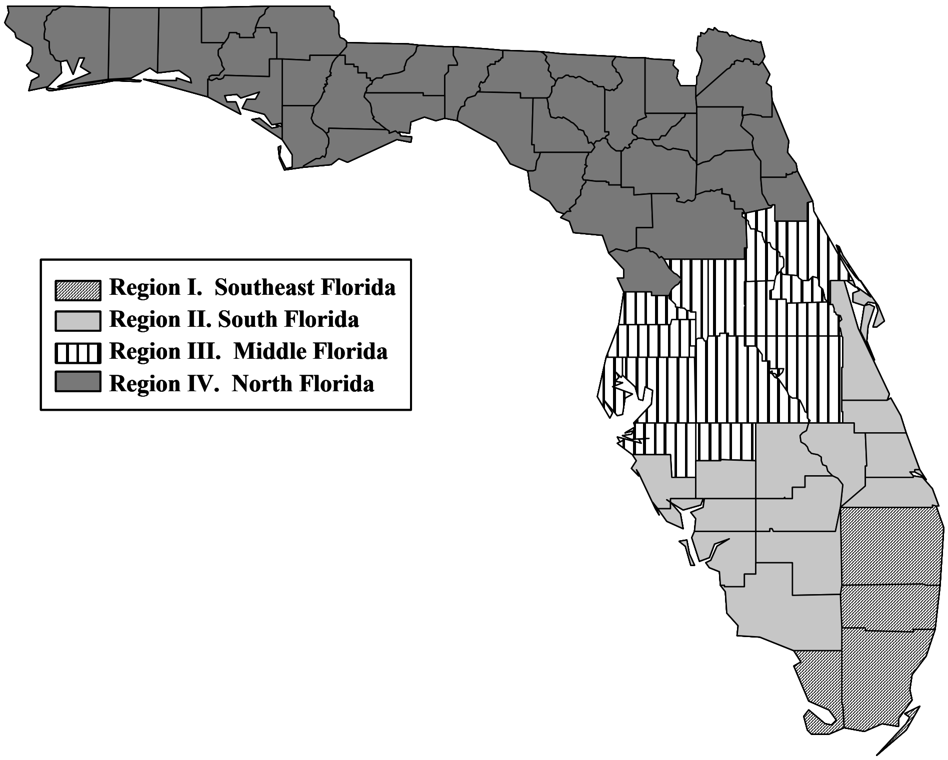


Figure I-17. Florida Building Stock Regions

Table I-3. Marginal Distributions from RCMP Data[1]

Region	Era	Roof Deck Attachment			Roof-Wall Connection				Glazed Opening Protection			Roof Shape		Roof Covering	
		A	B	C	Toe	Clip	Wrap	Db W	None	Basic	Hur	Other	Hip	FBC	Non-FBC
I. Southeast Florida	≤65	12	10	78	35	12	50	3	88	10	2	58	42	15	85
	66-94	37	48	14	4	5	86	5	83	14	3	62	38	15	85
	≥95	1	2	97	0	1	34	65	2	8	90	67	33	90	10
II. South Florida	≤65	25	20	55	54	15	28	4	93	5	2	58	42	0	100
	≥66	48	33	19	5	16	54	25	84	14	2	61	39	0	100
III. Middle Florida	≤65	8	14	78	72	17	6	5	97	2	1	70	30	0	100
	≥66	33	32	35	18	35	32	15	95	3	2	76	24	0	100
IV. North Florida	≤65	16	17	67	60	37	2	1	95	4	1	77	23	0	100
	≥66	44	39	18	11	80	7	2	92	6	2	72	28	0	100

[1] All values are expressed as percentages.

frequency of toe-nail connections is based on the RCMP re-inspection data. This analysis indicates toe-nail connections in 35% of the pre-1966 homes and 4% of the 1966-1994 homes. Zero percent of post-1994 homes in Region I are assumed to have toe-nails, consistent with the connection requirements of the 1994 SFBC.

For the distribution of non toe-nail connections in Region I, we evaluated earlier editions of the SFBC. This approach was required since the initial-year RCMP data in this Region does not facilitate the breakout of the strapped connections into clips, wraps, and double wraps. For the 1966-1994 era, review of the SFBC indicates that strapped connections have been required for roof-to-wall connections. We therefore assume that the majority of the non toe-nail connections are straps and allow for 5% each to be the equivalent of clips or double wraps. Similarly, for the pre-1966 Region I era, we allocate the majority of the non toe-nail connections into straps and allow for 12% clips and 3% double wrap strength connections.

Additional high quality inspection data is needed to improve these estimates of the roof-wall connection distribution within various regions of the state.

1.3.3 Roof Deck Attachment

The determination of roof deck attachment requires that the roof deck type and fastener size/spacing be determined. We therefore use a two-part approach to estimate the distribution of roof deck attachments.

The first step is to estimate the frequency distribution of plywood/OSB decks by region and era. Roof deck type was inspected accurately more than 91% of the time in each of the RCMP regions. Therefore, we use the actual frequency distributions from the RCMP data for each region with the following exceptions. For the pre-1966 construction in Lee County we used 50% plywood deck versus the 75% computed from the 8 inspections. This adjustment makes the Region II pre-1966 era more consistent with the other regions for this time period. The second exception is the Region III (Tampa area) data, which indicated a much lower (68%) percentage of plywood roof decks for post-1965 construction than found in the other regions. We adjusted this number up to 85% for this region, which compares more reasonably to the other frequencies of 91, 94, and 97 % for Regions I, II, and IV.

The proportion of plywood roof decks by region and era is given in Table I-4 along with other information that is used to compute the deck attachment proportions. The complement of the percentage of roof decks that are plywood yields the percentage of dimensional lumber/T&G roof decks. These latter roof decks qualify for Deck Attachment C, with an additional discount as discussed in Section 3. Hence, the percentage of roof decks that are dimensional lumber/T&G in each region and era provides us the proportion that qualify for Deck Attachment C with the dimensional lumber discount. Hence the column labeled Deck D has a proportion that is equal to one minus the plywood portion for that region and era.

The second step is to estimate the nail attachment size for the plywood/OSB roof decks. The quality of the RCMP deck nail size/spacing data varied with Region. For Southeast Florida, the nail size determination had a high error rate and so we used the re-inspection data, which provided 140 inspections with nail size determined. These proportions are given in the columns label nail size in Table I-4. With this information, the estimated frequencies for Deck Attachment A, B, and C are calculated by multiplying the nail size data by the frequency of plywood roof decks. The right hand side of Table I-4 gives the proportions of deck attachment. For purposes of displaying the information in terms of building stock distribution, we add the dimensional lumber proportion to the results for Deck Attachment C. Hence, the summed proportions for deck attachment equals 100%. Table I-4 also gives a column labeled C or D, which sums both deck attachments that go into final results shown in Table I-3.

For the Lee County RCMP data, there were only about 56 inspections that provided nail size/attachment data for plywood roof decks. Of these there were only 4 inspections for pre-1965 construction and these indicated 50% were 6d nail attachments. The remaining were 8d nails and we used judgment to

Table I-4. Computation of Roof Deck Attachment Proportions

Region	Era	Nail Size Given Plywood			Proportions of Deck Type			
		P(A|Ply)	P(B|Ply)	P(C|Ply)	Deck A	Deck B	Deck C	C or D
I. Southeast Florida	≤65	0.48	0.41	0.11	0.12	0.10	0.03	0.78
	66-94	0.41	0.53	0.06	0.37	0.48	0.05	0.14
	≥95	0.01	0.02	0.97	0.01	0.02	0.97	0.97
II. South Florida	≤65	0.50	0.40	0.10	0.25	0.2	0.05	0.55
	≥66	0.50	0.35	0.15	0.48	0.33	0.14	0.19
III. Middle Florida	≤65	0.30	0.50	0.20	0.08	0.14	0.05	0.78
	≥66	0.39	0.38	0.23	0.33	0.32	0.20	0.35
IV. North Florida	≤65	0.44	0.47	0.09	0.16	0.17	0.03	0.67
	≥66	0.45	0.40	0.15	0.44	0.39	0.15	0.18

proportion those as shown in Table I-4. For the post-1966 construction era, the actual data shows a higher percentage of 6d decks (73%) that is not consistent with the rest of the state. We adjusted this proportion down to 50%, which is more in line with the other regions. Another problem with the Lee data was that the actual data had zero frequency of Deck Attachment B, which is not realistic. The remaining proportions were therefore estimated using judgment based on trends in Regions I and III.

For the Tampa area inspections, we used the actual deck attachment inspection data for the post-1966 era as there were 95 inspections that gave plywood deck attachment. For the pre-1966 era, there were only 11 inspections that gave deck attachment and we used this data with some slight smoothing.

For the Panhandle inspections, we use the actual data since there were 495 inspections that gave us nail size and spacing data. These proportions and the computed Deck Attachment distributions are given in Table I-4 and carried over to Table I-3.

We see a strong effect of era on the frequency of deck attachments. The dimensional lumber/T&G decks result in a large percentage of the pre-1966 construction qualify as Attachment C or better. The post-1994 construction in Region I also has a high percentage of Deck attachment C, by virtue of the SFBC and the improved specifications for deck attachment.

I.3.4 Opening Protection

The actual RCMP data is used to determine the frequency of opening protection. The RCMP QA re-inspection program in Southeast Florida indicated that inspectors correctly identified the level of opening protection about 90% of the time. The RCMP re-inspection program did not focus on opening protection for the other RCMP regions and hence there is no confirmation of the quality of the opening protection data for other regions. However, as the training improved every year, there is little reason to expect that the data is not as good or better that the SE Florida data.

The analysis of the RCMP data includes protection for glazed openings only. It considers two levels of protection, basic, and hurricane. Hurricane protection is based on 1994 SFBC or SSTD 12 opening protection for missile impact and pressure cycling loads. In order to qualify for all glazed openings hurricane protected, the inspectors had to find the appropriate labels on all protection devices. Otherwise the buildings were rated as either none or basic depending on whether all openings were protected to some level. Basic protection was estimated by analyzing the RCMP data for some type of opening protection on all glazed openings.

The results in Table I-3 were obtained directly from the RCMP with the following exceptions. For pre-1966 construction in Region II, there were only 8 inspections. The opening protection frequencies for Region II were obtained by averaging the Region I and Region III frequencies. Secondly, the hurricane and basic protection were increased by 1-2% to reflect that QA reinspections show that the inspectors did not always find labels that were present.

The frequencies in Table I-3, of course, do not reflect the installation of plywood panels over windows that some homeowners will install. The RCMP inspections did not attempt to determine if homeowners would install such devices. Unless these panels are installed with adequate fasteners per the procedures in SSTD 12, it is difficult to determine the utility of such panels as the panels may fail from the pressure cycling loads.

I.3.5 Roof Covering

The 1994 SFBC introduced improved roof covering specifications that are similar to those of the new FBC roof covering specifications. We judged these similarities to be sufficient such that those homes with 1994 SFBC roof coverings should qualify for the FBC equivalent roof covering discounts in the main relativity tables in this report. Therefore, existing construction in Region I that have been retrofitted with 1994 SFBC roof covers should qualify for the FBC roof covering credit.

Two conditional probabilities are needed to estimate the distribution of business for houses in Region I that have had 1994 SFBC roof covers installed. The first is $P(N_{rc}|Y_{\geq 1995})$, which is the probability of a house with a new roof cover (N_{rc}) that was built during or after 1995. The second is $P(N_{rc}|Y_{<1995})$, which is the probability of a house built prior to 1995 having been recovered with a new SFBC roof.

$P(N_{rc}|Y_{\geq 1995})$ would be estimated as unity with perfect construction quality and code compliance. We use a value of 0.9 herein for homes built after 1995 to allow for lack of perfect construction compliance with the 1994 SFBC.

$P(N_{rc}|Y_{<1995})$ is estimated as 0.15, assuming: (1) the average number of years between new roof covers is 30 years for tile roofs and 15 for shingles; (2) that 45% of the roof covers in Region I are tiles; (3) and that there have been 7 years of new roof covers from 1995-2001; (4) that 90% of the roof covers have been installed properly according to the 1994 SFBC specifications; and (5) that 51% of the homes in Region I would likely be potentially recovered, based on analysis of age distribution in Dade and Broward Counties. The calculation is:

$$P(N_{rc}|Y_{<1995}) = 7 \text{ yrs}/(0.45 \times 30 \text{ yrs} + 0.55 \text{ x } 15 \text{ yrs}) \times 0.9 \times 0.51 = 0.15$$

The 51% value was computed using the year built tax record data for the years <1985 for Miami-Dade and Broward Counties, normalized by the total number of homes built in Region I prior to 1995. This calculation therefore assumes that houses built between 1986 and 1994 are not old enough to have required a new SFBC roof cover as of 2002.

For other regions, we assume there are essentially no roof covers that have been installed on existing construction that are equivalent to the new FBC. While there may some houses in these other regions with FBC equivalent roof covers, the number is likely less than 1% and will not practically affect the calculation of average rating factor.

I.3.6 Secondary Rating Factors

Similar to the analysis of the RCMP data for the primary rating factors, we have evaluated that dataset and others to produce estimates of the building stock distribution for the secondary rating factors. Table I-5 summarizes these results.

The fraction of homes with reinforced concrete roof decks has been estimated based using FWUA inspection data coupled with judgment. We estimated totals of 500, 75, 50, and 20 houses with reinforced concrete roof decks in Regions I through IV respectively. These numbers were then proportioned to era using the FWUA inspection data and divided by the number of residences from the tax record database. The resulting fractions in Table I-5 are extremely small and do not practically affect the calculation of average rating factors.

The fraction of Deck Attachment C houses in that qualify as dimensional lumber (Deck Attachment D) comes directly from Table I-4. These fractions were obtained by dividing the column labeled "C" by the column labeled "C or D" and subtracting the computed number from unity to give the conditional probability of a deck being "D".

The fraction of total residences that have masonry walls was estimated from the RCMP database. The only exception was the Region IV post 1965 era in which we increased the RCMP percent masonry from 2% to 5%. The resulting percentages of homes that have masonry walls is different from the 2001/2002 Florida Hurricane Catastrophe Fund Ratemaking Data, particularly in Region IV. The Ratemaking data yields percentages of 93,76,79, and 41 for Regions I through IV. An exact comparison is not possible because of the categories for Residential in the Ratemaking data. We believe the Ratemaking dataset overestimates the percentage of masonry walled homes, since many insurer datasets include misclassifications of brick veneer wood frame homes as masonry. Therefore, we have used the RCMP data a noted above.

The fractions of masonry walled homes with reinforcing was estimated directly from the FWUA inspection data. These fraction of reinforced and unreinforced in Table I-5 sum to the total fraction for masonry walls.

The fraction of "other" roof shapes that have unbraced gable ends were estimated from the FWUA inspection data.

The fraction of homes with opening protection for all openings was estimated from the RCMP dataset. These fractions in Table I-5 represent the proportion of homes with glazed openings protected that also have all openings protected.

I.4 Building Stock Distribution Tables

The building stock distribution tables that match the format of the existing construction relativity tables are given in Tables I-6 through I-14. These tables do not include any corrections for any of the secondary rating factor distributions in Table I-5.

The conditional probabilities in Tables I-6 through I-14 sum to unity. The probability in each cell is the product of the proportions from Table I-3. These tables can be used directly by an insurer to construct a portfolio-specific estimation of the distribution of business according to the primary rating factors. Alternately, if an insurer has better information than used to develop these tables, then a customized set of tables could alternately be produced.

To include the effects of secondary rating factors, the information in Table I-5 can be used to refine the distributions of business in Tables I-6 through I-14. This can be done by direct calculations using the information in Table I-5.

Table I-5. Secondary Rating Factor Distribution

Region	Era	Reinforced Concrete Deck	Dimensional Lumber	Masonry Walls			Other Roof Shape	Foundation	Opening Protection
		Fraction of Residences	Fraction of Deck C	Fraction of Total Residences	Fraction of Total that are Unreinforced	Fraction of Total that are Reinforced	Fraction of Other that are Unbraced	Fraction of Total Residences that are Unrestrained	Fraction of Protected Openings that have All Openings Protected
I	≤65	0.00025	0.965	0.83	0.4067	0.4233	0.48	0.004	0.16
	66-94	0.00056	0.622	0.83	0.1992	0.6308	0.59	0	0.16
	≥95	0.00214	0.000	0.83	0.0166	0.8134	0.30	0	0.85
II	≤65	0.00000	0.909	0.63	0.2331	0.3969	0.74	0.004	0.16
	≥66	0.00014	0.260	0.72	0.0648	0.6552	0.61	0	0.16
III	≤65	0.00000	0.931	0.72	0.2448	0.4752	0.73	0.004	0.2
	≥66	0.00005	0.434	0.65	0.1625	0.4875	0.80	0	0.2
IV	≤65	0.00000	0.952	0.2	0.134	0.066	0.82	0.004	0.18
	≥66	0.00004	0.178	0.05	0.025	0.025	0.57	0	0.18

Table I-6. Region I. Southeast Florida ≤1965 Distribution of Business

Building Stock Distribution-SE Florida ≤1965				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	1.822E-02		1.319E-02	
			Basic	2.071E-03		1.499E-03	
			Hurricane	4.141E-04		2.999E-04	
		Clips	None	6.247E-03		4.524E-03	
			Basic	7.099E-04		5.141E-04	
			Hurricane	1.420E-04		1.028E-04	
		Single Wraps	None	2.603E-02		1.885E-02	
			Basic	2.958E-03		2.142E-03	
			Hurricane	5.916E-04		4.284E-04	
		Double Wraps	None	1.562E-03		1.131E-03	
			Basic	1.775E-04		1.285E-04	
			Hurricane	3.550E-05		2.570E-05	
	B. (8d @ 6"/12")	Toe Nails	None	1.556E-02		1.127E-02	
			Basic	1.769E-03		1.281E-03	
			Hurricane	3.537E-04		2.561E-04	
		Clips	None	5.336E-03		3.864E-03	
			Basic	6.064E-04		4.391E-04	
			Hurricane	1.213E-04		8.782E-05	
		Single Wraps	None	2.223E-02		1.610E-02	
			Basic	2.527E-03		1.830E-03	
			Hurricane	5.053E-04		3.659E-04	
		Double Wraps	None	1.334E-03		9.660E-04	
			Basic	1.516E-04		1.098E-04	
			Hurricane	3.032E-05		2.196E-05	
	C. (8d @ 6"/6")	Toe Nails	None	1.181E-01		8.549E-02	
			Basic	1.342E-02		9.715E-03	
			Hurricane	2.683E-03		1.943E-03	
		Clips	None	4.048E-02		2.931E-02	
			Basic	4.600E-03		3.331E-03	
			Hurricane	9.199E-04		6.662E-04	
		Single Wraps	None	1.687E-01		1.221E-01	
			Basic	1.917E-02		1.388E-02	
			Hurricane	3.833E-03		2.776E-03	
		Double Wraps	None	1.012E-02		7.328E-03	
			Basic	1.150E-03		8.327E-04	
			Hurricane	2.300E-04		1.665E-04	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	3.216E-03		2.328E-03	
			Basic	3.654E-04		2.646E-04	
			Hurricane	7.308E-05		5.292E-05	
		Clips	None	1.102E-03		7.983E-04	
			Basic	1.253E-04		9.072E-05	
			Hurricane	2.506E-05		1.814E-05	
		Single Wraps	None	4.594E-03		3.326E-03	
			Basic	5.220E-04		3.780E-04	
			Hurricane	1.044E-04		7.560E-05	
		Double Wraps	None	2.756E-04		1.996E-04	
			Basic	3.132E-05		2.268E-05	
			Hurricane	6.264E-06		4.536E-06	
	B. (8d @ 6"/12")	Toe Nails	None	2.747E-03		1.989E-03	
			Basic	3.121E-04		2.260E-04	
			Hurricane	6.242E-05		4.520E-05	
		Clips	None	9.417E-04		6.819E-04	
			Basic	1.070E-04		7.749E-05	
			Hurricane	2.140E-05		1.550E-05	
		Single Wraps	None	3.924E-03		2.841E-03	
			Basic	4.459E-04		3.229E-04	
			Hurricane	8.918E-05		6.458E-05	
		Double Wraps	None	2.354E-04		1.705E-04	
			Basic	2.675E-05		1.937E-05	
			Hurricane	5.351E-06		3.875E-06	
	C. (8d @ 6"/6")	Toe Nails	None	2.083E-02		1.509E-02	
			Basic	2.367E-03		1.714E-03	
			Hurricane	4.735E-04		3.429E-04	
		Clips	None	7.143E-03		5.173E-03	
			Basic	8.117E-04		5.878E-04	
			Hurricane	1.623E-04		1.176E-04	
		Single Wraps	None	2.976E-02		2.155E-02	
			Basic	3.382E-03		2.449E-03	
			Hurricane	6.764E-04		4.898E-04	
		Double Wraps	None	1.786E-03		1.293E-03	
			Basic	2.029E-04		1.469E-04	
			Hurricane	4.059E-05		2.939E-05	

Table I-7. Region I. Southeast Florida 1966-1994 Distribution of Business

Building Stock Distribution- SE Florida 1966-1994				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	6.528E-03		4.001E-03	
			Basic	1.022E-03		6.267E-04	
			Hurricane	3.146E-04		1.928E-04	
		Clips	None	8.160E-03		5.001E-03	
			Basic	1.278E-03		7.833E-04	
			Hurricane	3.932E-04		2.410E-04	
		Single Wraps	None	1.403E-01		8.602E-02	
			Basic	2.198E-02		1.347E-02	
			Hurricane	6.764E-03		4.146E-03	
		Double Wraps	None	8.160E-03		5.001E-03	
			Basic	1.278E-03		7.833E-04	
			Hurricane	3.932E-04		2.410E-04	
	B. (8d @ 6"/12")	Toe Nails	None	8.439E-03		5.172E-03	
			Basic	1.322E-03		8.101E-04	
			Hurricane	4.067E-04		2.493E-04	
		Clips	None	1.055E-02		6.465E-03	
			Basic	1.652E-03		1.013E-03	
			Hurricane	5.083E-04		3.116E-04	
		Single Wraps	None	1.814E-01		1.112E-01	
			Basic	2.842E-02		1.742E-02	
			Hurricane	8.744E-03		5.359E-03	
		Double Wraps	None	1.055E-02		6.465E-03	
			Basic	1.652E-03		1.013E-03	
			Hurricane	5.083E-04		3.116E-04	
	C. (8d @ 6"/6")	Toe Nails	None	2.530E-03		1.551E-03	
			Basic	3.963E-04		2.429E-04	
			Hurricane	1.219E-04		7.473E-05	
		Clips	None	3.162E-03		1.938E-03	
			Basic	4.953E-04		3.036E-04	
			Hurricane	1.524E-04		9.341E-05	
		Single Wraps	None	5.439E-02		3.334E-02	
			Basic	8.520E-03		5.222E-03	
			Hurricane	2.621E-03		1.607E-03	
		Double Wraps	None	3.162E-03		1.938E-03	
			Basic	4.953E-04		3.036E-04	
			Hurricane	1.524E-04		9.341E-05	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	1.152E-03		7.061E-04	
			Basic	1.804E-04		1.106E-04	
			Hurricane	5.552E-05		3.403E-05	
		Clips	None	1.440E-03		8.826E-04	
			Basic	2.255E-04		1.382E-04	
			Hurricane	6.940E-05		4.253E-05	
		Single Wraps	None	2.477E-02		1.518E-02	
			Basic	3.879E-03		2.378E-03	
			Hurricane	1.194E-03		7.316E-04	
		Double Wraps	None	1.440E-03		8.826E-04	
			Basic	2.255E-04		1.382E-04	
			Hurricane	6.940E-05		4.253E-05	
	B. (8d @ 6"/12")	Toe Nails	None	1.489E-03		9.127E-04	
			Basic	2.332E-04		1.430E-04	
			Hurricane	7.177E-05		4.399E-05	
		Clips	None	1.861E-03		1.141E-03	
			Basic	2.916E-04		1.787E-04	
			Hurricane	8.971E-05		5.498E-05	
		Single Wraps	None	3.202E-02		1.962E-02	
			Basic	5.015E-03		3.074E-03	
			Hurricane	1.543E-03		9.457E-04	
		Double Wraps	None	1.861E-03		1.141E-03	
			Basic	2.916E-04		1.787E-04	
			Hurricane	8.971E-05		5.498E-05	
	C. (8d @ 6"/6")	Toe Nails	None	4.465E-04		2.736E-04	
			Basic	6.993E-05		4.286E-05	
			Hurricane	2.152E-05		1.319E-05	
		Clips	None	5.581E-04		3.421E-04	
			Basic	8.741E-05		5.357E-05	
			Hurricane	2.690E-05		1.648E-05	
		Single Wraps	None	9.599E-03		5.883E-03	
			Basic	1.503E-03		9.215E-04	
			Hurricane	4.626E-04		2.835E-04	
		Double Wraps	None	5.581E-04		3.421E-04	
			Basic	8.741E-05		5.357E-05	
			Hurricane	2.690E-05		1.648E-05	

Table I-8. Region I. Southeast Florida ≥1995 Distribution of Business

Building Stock Distribution- SE Florida ≥1995				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	0.000E+00		0.000E+00	
			Basic	0.000E+00		0.000E+00	
			Hurricane	0.000E+00		0.000E+00	
		Clips	None	1.240E-07		7.600E-08	
			Basic	4.960E-07		3.040E-07	
			Hurricane	5.580E-06		3.420E-06	
		Single Wraps	None	4.216E-06		2.584E-06	
			Basic	1.686E-05		1.034E-05	
			Hurricane	1.897E-04		1.163E-04	
		Double Wraps	None	8.060E-06		4.940E-06	
			Basic	3.224E-05		1.976E-05	
			Hurricane	3.627E-04		2.223E-04	
	B. (8d @ 6"/12")	Toe Nails	None	0.000E+00		0.000E+00	
			Basic	0.000E+00		0.000E+00	
			Hurricane	0.000E+00		0.000E+00	
		Clips	None	2.480E-07		1.520E-07	
			Basic	9.920E-07		6.080E-07	
			Hurricane	1.116E-05		6.840E-06	
		Single Wraps	None	8.432E-06		5.168E-06	
			Basic	3.373E-05		2.067E-05	
			Hurricane	3.794E-04		2.326E-04	
		Double Wraps	None	1.612E-05		9.880E-06	
			Basic	6.448E-05		3.952E-05	
			Hurricane	7.254E-04		4.446E-04	
	C. (8d @ 6"/6")	Toe Nails	None	0.000E+00		0.000E+00	
			Basic	0.000E+00		0.000E+00	
			Hurricane	0.000E+00		0.000E+00	
		Clips	None	1.203E-05		7.372E-06	
			Basic	4.811E-05		2.949E-05	
			Hurricane	5.413E-04		3.317E-04	
		Single Wraps	None	4.090E-04		2.506E-04	
			Basic	1.636E-03		1.003E-03	
			Hurricane	1.840E-02		1.128E-02	
		Double Wraps	None	7.818E-04		4.792E-04	
			Basic	3.127E-03		1.917E-03	
			Hurricane	3.518E-02		2.156E-02	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	0.000E+00		0.000E+00	
			Basic	0.000E+00		0.000E+00	
			Hurricane	0.000E+00		0.000E+00	
		Clips	None	1.116E-06		6.840E-07	
			Basic	4.464E-06		2.736E-06	
			Hurricane	5.022E-05		3.078E-05	
		Single Wraps	None	3.794E-05		2.326E-05	
			Basic	1.518E-04		9.302E-05	
			Hurricane	1.707E-03		1.047E-03	
		Double Wraps	None	7.254E-05		4.446E-05	
			Basic	2.902E-04		1.778E-04	
			Hurricane	3.264E-03		2.001E-03	
	B. (8d @ 6"/12")	Toe Nails	None	0.000E+00		0.000E+00	
			Basic	0.000E+00		0.000E+00	
			Hurricane	0.000E+00		0.000E+00	
		Clips	None	2.232E-06		1.368E-06	
			Basic	8.928E-06		5.472E-06	
			Hurricane	1.004E-04		6.156E-05	
		Single Wraps	None	7.589E-05		4.651E-05	
			Basic	3.036E-04		1.860E-04	
			Hurricane	3.415E-03		2.093E-03	
		Double Wraps	None	1.451E-04		8.892E-05	
			Basic	5.803E-04		3.557E-04	
			Hurricane	6.529E-03		4.001E-03	
	C. (8d @ 6"/6")	Toe Nails	None	0.000E+00		0.000E+00	
			Basic	0.000E+00		0.000E+00	
			Hurricane	0.000E+00		0.000E+00	
		Clips	None	1.083E-04		6.635E-05	
			Basic	4.330E-04		2.654E-04	
			Hurricane	4.871E-03		2.986E-03	
		Single Wraps	None	3.681E-03		2.256E-03	
			Basic	1.472E-02		9.023E-03	
			Hurricane	1.656E-01		1.015E-01	
		Double Wraps	None	7.036E-03		4.313E-03	
			Basic	2.815E-02		1.725E-02	
			Hurricane	3.166E-01		1.941E-01	

Table I-9. Region II. South Florida ≤1965 Distribution of Business

Building Stock Distribution-South Florida ≤1965				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	7.214E-02		5.224E-02	
			Basic	3.879E-03		2.809E-03	
			Hurricane	1.552E-03		1.124E-03	
		Clips	None	1.955E-02		1.416E-02	
			Basic	1.051E-03		7.613E-04	
			Hurricane	4.205E-04		3.045E-04	
		Single Wraps	None	3.776E-02		2.734E-02	
			Basic	2.030E-03		1.470E-03	
			Hurricane	8.120E-04		5.880E-04	
		Double Wraps	None	5.394E-03		3.906E-03	
			Basic	2.900E-04		2.100E-04	
			Hurricane	1.160E-04		8.400E-05	
	B. (8d @ 6"/12")	Toe Nails	None	5.772E-02		4.179E-02	
			Basic	3.103E-03		2.247E-03	
			Hurricane	1.241E-03		8.988E-04	
		Clips	None	1.564E-02		1.133E-02	
			Basic	8.410E-04		6.090E-04	
			Hurricane	3.364E-04		2.436E-04	
		Single Wraps	None	3.021E-02		2.187E-02	
			Basic	1.624E-03		1.176E-03	
			Hurricane	6.496E-04		4.704E-04	
		Double Wraps	None	4.315E-03		3.125E-03	
			Basic	2.320E-04		1.680E-04	
			Hurricane	9.280E-05		6.720E-05	
	C. (8d @ 6"/6")	Toe Nails	None	1.587E-01		1.149E-01	
			Basic	8.533E-03		6.179E-03	
			Hurricane	3.413E-03		2.472E-03	
		Clips	None	4.302E-02		3.115E-02	
			Basic	2.313E-03		1.675E-03	
			Hurricane	9.251E-04		6.699E-04	
		Single Wraps	None	8.307E-02		6.015E-02	
			Basic	4.466E-03		3.234E-03	
			Hurricane	1.786E-03		1.294E-03	
		Double Wraps	None	1.187E-02		8.593E-03	
			Basic	6.380E-04		4.620E-04	
			Hurricane	2.552E-04		1.848E-04	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				

Table I-10. Region II. South Florida ≥1966 Distribution of Business

Building Stock Distribution-South Florida ≥1966				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	1.217E-02		7.781E-03	
			Basic	2.028E-03		1.297E-03	
			Hurricane	2.898E-04		1.853E-04	
		Clips	None	3.894E-02		2.490E-02	
			Basic	6.490E-03		4.150E-03	
			Hurricane	9.272E-04		5.928E-04	
		Single Wraps	None	1.314E-01		8.403E-02	
			Basic	2.191E-02		1.400E-02	
			Hurricane	3.129E-03		2.001E-03	
		Double Wraps	None	6.085E-02		3.890E-02	
			Basic	1.014E-02		6.484E-03	
			Hurricane	1.449E-03		9.263E-04	
	B. (8d @ 6"/12")	Toe Nails	None	8.519E-03		5.446E-03	
			Basic	1.420E-03		9.077E-04	
			Hurricane	2.028E-04		1.297E-04	
		Clips	None	2.726E-02		1.743E-02	
			Basic	4.543E-03		2.905E-03	
			Hurricane	6.490E-04		4.150E-04	
		Single Wraps	None	9.200E-02		5.882E-02	
			Basic	1.533E-02		9.803E-03	
			Hurricane	2.191E-03		1.400E-03	
		Double Wraps	None	4.259E-02		2.723E-02	
			Basic	7.099E-03		4.539E-03	
			Hurricane	1.014E-03		6.484E-04	
	C. (8d @ 6"/6")	Toe Nails	None	4.932E-03		3.153E-03	
			Basic	8.220E-04		5.255E-04	
			Hurricane	1.174E-04		7.508E-05	
		Clips	None	1.578E-02		1.009E-02	
			Basic	2.630E-03		1.682E-03	
			Hurricane	3.758E-04		2.402E-04	
		Single Wraps	None	5.326E-02		3.405E-02	
			Basic	8.877E-03		5.676E-03	
			Hurricane	1.268E-03		8.108E-04	
		Double Wraps	None	2.466E-02		1.577E-02	
			Basic	4.110E-03		2.628E-03	
			Hurricane	5.871E-04		3.754E-04	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				

Table I-11. Region III. Middle Florida ≤1965 Distribution of Business

Building Stock Distribution- Mid Florida ≤1965				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	3.960E-02		1.697E-02	
			Basic	8.165E-04		3.499E-04	
			Hurricane	4.082E-04		1.750E-04	
		Clips	None	9.350E-03		4.007E-03	
			Basic	1.928E-04		8.262E-05	
			Hurricane	9.639E-05		4.131E-05	
		Single Wraps	None	3.300E-03		1.414E-03	
			Basic	6.804E-05		2.916E-05	
			Hurricane	3.402E-05		1.458E-05	
		Double Wraps	None	2.750E-03		1.179E-03	
			Basic	5.670E-05		2.430E-05	
			Hurricane	2.835E-05		1.215E-05	
	B. (8d @ 6"/12")	Toe Nails	None	6.600E-02		2.829E-02	
			Basic	1.361E-03		5.832E-04	
			Hurricane	6.804E-04		2.916E-04	
		Clips	None	1.558E-02		6.678E-03	
			Basic	3.213E-04		1.377E-04	
			Hurricane	1.607E-04		6.885E-05	
		Single Wraps	None	5.500E-03		2.357E-03	
			Basic	1.134E-04		4.860E-05	
			Hurricane	5.670E-05		2.430E-05	
		Double Wraps	None	4.583E-03		1.964E-03	
			Basic	9.450E-05		4.050E-05	
			Hurricane	4.725E-05		2.025E-05	
	C. (8d @ 6"/6")	Toe Nails	None	3.833E-01		1.643E-01	
			Basic	7.903E-03		3.387E-03	
			Hurricane	3.951E-03		1.693E-03	
		Clips	None	9.050E-02		3.878E-02	
			Basic	1.866E-03		7.997E-04	
			Hurricane	9.330E-04		3.998E-04	
		Single Wraps	None	3.194E-02		1.369E-02	
			Basic	6.586E-04		2.822E-04	
			Hurricane	3.293E-04		1.411E-04	
		Double Wraps	None	2.662E-02		1.141E-02	
			Basic	5.488E-04		2.352E-04	
			Hurricane	2.744E-04		1.176E-04	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				

Table I-12. Region III. Middle Florida ≥1966 Distribution of Business

Building Stock Distribution- Mid Florida ≥1966				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	4.308E-02		1.360E-02	
			Basic	1.360E-03		4.296E-04	
			Hurricane	9.070E-04		2.864E-04	
		Clips	None	8.377E-02		2.645E-02	
			Basic	2.645E-03		8.354E-04	
			Hurricane	1.764E-03		5.569E-04	
		Single Wraps	None	7.659E-02		2.419E-02	
			Basic	2.419E-03		7.638E-04	
			Hurricane	1.612E-03		5.092E-04	
		Double Wraps	None	3.590E-02		1.134E-02	
			Basic	1.134E-03		3.580E-04	
			Hurricane	7.558E-04		2.387E-04	
	B. (8d @ 6"/12")	Toe Nails	None	4.198E-02		1.326E-02	
			Basic	1.326E-03		4.186E-04	
			Hurricane	8.837E-04		2.791E-04	
		Clips	None	8.162E-02		2.578E-02	
			Basic	2.578E-03		8.140E-04	
			Hurricane	1.718E-03		5.426E-04	
		Single Wraps	None	7.463E-02		2.357E-02	
			Basic	2.357E-03		7.442E-04	
			Hurricane	1.571E-03		4.961E-04	
		Double Wraps	None	3.498E-02		1.105E-02	
			Basic	1.105E-03		3.488E-04	
			Hurricane	7.364E-04		2.326E-04	
	C. (8d @ 6"/6")	Toe Nails	None	4.490E-02		1.418E-02	
			Basic	1.418E-03		4.478E-04	
			Hurricane	9.453E-04		2.985E-04	
		Clips	None	8.731E-02		2.757E-02	
			Basic	2.757E-03		8.707E-04	
			Hurricane	1.838E-03		5.804E-04	
		Single Wraps	None	7.982E-02		2.521E-02	
			Basic	2.521E-03		7.960E-04	
			Hurricane	1.681E-03		5.307E-04	
		Double Wraps	None	3.742E-02		1.182E-02	
			Basic	1.182E-03		3.731E-04	
			Hurricane	7.877E-04		2.488E-04	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				

Table I-13. Region IV. North Florida ≤1965 Distribution of Business

Building Stock Distribution- North Florida ≤1965				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	6.952E-02		2.077E-02	
			Basic	2.927E-03		8.744E-04	
			Hurricane	7.318E-04		2.186E-04	
		Clips	None	4.287E-02		1.281E-02	
			Basic	1.805E-03		5.392E-04	
			Hurricane	4.513E-04		1.348E-04	
		Single Wraps	None	2.317E-03		6.922E-04	
			Basic	9.757E-05		2.915E-05	
			Hurricane	2.439E-05		7.286E-06	
		Double Wraps	None	1.159E-03		3.461E-04	
			Basic	4.879E-05		1.457E-05	
			Hurricane	1.220E-05		3.643E-06	
	B. (8d @ 6"/12")	Toe Nails	None	7.426E-02		2.218E-02	
			Basic	3.127E-03		9.340E-04	
			Hurricane	7.817E-04		2.335E-04	
		Clips	None	4.579E-02		1.368E-02	
			Basic	1.928E-03		5.760E-04	
			Hurricane	4.821E-04		1.440E-04	
		Single Wraps	None	2.475E-03		7.394E-04	
			Basic	1.042E-04		3.113E-05	
			Hurricane	2.606E-05		7.783E-06	
		Double Wraps	None	1.238E-03		3.697E-04	
			Basic	5.211E-05		1.557E-05	
			Hurricane	1.303E-05		3.892E-06	
	C. (8d @ 6"/6")	Toe Nails	None	2.951E-01		8.815E-02	
			Basic	1.243E-02		3.712E-03	
			Hurricane	3.106E-03		9.279E-04	
		Clips	None	1.820E-01		5.436E-02	
			Basic	7.663E-03		2.289E-03	
			Hurricane	1.916E-03		5.722E-04	
		Single Wraps	None	9.837E-03		2.938E-03	
			Basic	4.142E-04		1.237E-04	
			Hurricane	1.035E-04		3.093E-05	
		Double Wraps	None	4.919E-03		1.469E-03	
			Basic	2.071E-04		6.186E-05	
			Hurricane	5.177E-05		1.547E-05	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None				
			Basic				
			Hurricane				
		Clips	None				
			Basic				
			Hurricane				
		Single Wraps	None				
			Basic				
			Hurricane				
		Double Wraps	None				
			Basic				
			Hurricane				

Table I-14. North Florida ≥1966 Distribution of Business

Building Stock Distribution- North Florida ≥1966				Roof Shape			
				Other		Hip	
Roof Cover	Roof Deck Attachment	Roof-Wall Connection	Opening Protection	No Secondary Water Resistance	Secondary Water Resistance	No Secondary Water Resistance	Secondary Water Resistance
Non-FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None	3.176E-02		1.235E-02	
			Basic	2.071E-03		8.055E-04	
			Hurricane	6.904E-04		2.685E-04	
		Clips	None	2.310E-01		8.983E-02	
			Basic	1.506E-02		5.858E-03	
			Hurricane	5.021E-03		1.953E-03	
		Single Wraps	None	2.021E-02		7.860E-03	
			Basic	1.318E-03		5.126E-04	
			Hurricane	4.394E-04		1.709E-04	
		Double Wraps	None	5.775E-03		2.246E-03	
			Basic	3.766E-04		1.465E-04	
			Hurricane	1.255E-04		4.882E-05	
	B. (8d @ 6"/12")	Toe Nails	None	2.823E-02		1.098E-02	
			Basic	1.841E-03		7.160E-04	
			Hurricane	6.137E-04		2.387E-04	
		Clips	None	2.053E-01		7.985E-02	
			Basic	1.339E-02		5.207E-03	
			Hurricane	4.463E-03		1.736E-03	
		Single Wraps	None	1.797E-02		6.987E-03	
			Basic	1.172E-03		4.556E-04	
			Hurricane	3.906E-04		1.519E-04	
		Double Wraps	None	5.133E-03		1.996E-03	
			Basic	3.348E-04		1.302E-04	
			Hurricane	1.116E-04		4.340E-05	
	C. (8d @ 6"/6")	Toe Nails	None	1.287E-02		5.006E-03	
			Basic	8.395E-04		3.265E-04	
			Hurricane	2.798E-04		1.088E-04	
		Clips	None	9.361E-02		3.641E-02	
			Basic	6.105E-03		2.374E-03	
			Hurricane	2.035E-03		7.914E-04	
		Single Wraps	None	8.191E-03		3.185E-03	
			Basic	5.342E-04		2.077E-04	
			Hurricane	1.781E-04		6.925E-05	
		Double Wraps	None	2.340E-03		9.101E-04	
			Basic	1.526E-04		5.936E-05	
			Hurricane	5.088E-05		1.979E-05	
FBC Equivalent	A. (6d @ 6"/12")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				
	B. (8d @ 6"/12")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				
	C. (8d @ 6"/6")	Toe Nails	None Basic Hurricane				
		Clips	None Basic Hurricane				
		Single Wraps	None Basic Hurricane				
		Double Wraps	None Basic Hurricane				