Residential Roofing And Hurricanes

June 2005
Version 1.0

Florida Building Commission
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Preface

This publication contains a PowerPoint presentation with notes representing a case study via photographic review on the performance of various types of residential roofing during the 2004 Florida storms. An overview of hurricanes, wind dynamics, why it is important to follow due diligence in the design, installation, and inspection of roofs and their substrates along with some related information relative to the roofing chapter of the *2004 Florida Building Code, Residential* (excluding High Velocity Hurricane Zone areas, which are covered in Chapter R44) are also included.

The *2004 Florida Building Code, Residential* is based on the *International Residential Code*®, which represents a significant change in both code format and content. It is strongly advised that participants review the entire *2004 Florida Residential Building Code, Residential*.

Special thanks are extended to the Wind Investigation Program teams of The Roofing Industry Committee on Weather Issues, Inc. (RICOWI) for sharing slides and information relative to their preliminary findings of residential roofing investigations following Hurricanes Charley and Ivan in 2004. Check their web site www.ricowi.com for availability of the full report. We also appreciate Mr. Bill Zoeller, Steven Winter Associates, for providing some of the images. Excerpts from the *2004 Florida Building Code, Residential* are also included (source: International Code Council, Inc.).

Reviewers:

- Mr. Steve Munnell, Executive Director, Florida Roofing, Sheet Metal and Air Conditioning Contractors Association
- Mr. Marvin "Skip" Murdock, Building Inspector, Citrus County Building Division
- Mr. Will Swanson, B.S.C.E., M.E.

Products referenced in this course are for illustration only and are not an endorsement, warrant, or representation by the author or instructor that the product meets the requirements of the 2004 *Florida Building Code, Residential*. Use of all products requires the approval of the local jurisdictional authority.

For more information regarding the Florida Building Code contact:

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To obtain a complete copy of the 2004 Florida Building Code contact The Florida Department of Community Affairs Building Code Information System Web site:

http://www.floridabuilding.org

The Florida Energy Extension Service worked with Building A Safer Florida, Inc. under contract to the Florida Building Commission through the Florida Department of Community Affairs to develop Version 1.0 of this program. Dr. Kathleen Ruppert coordinated development of the program and Ms. Barbara Haldeman provided layout and design services.

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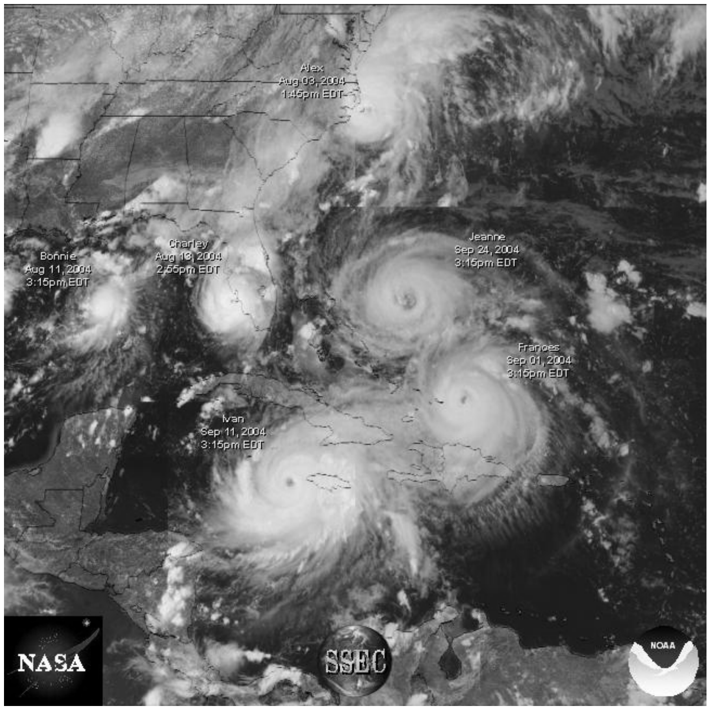
1

The following presentation offers a case study via photographic review on the performance of various types of residential roofing during the 2004 Florida storms. An overview of hurricanes, wind dynamics, why it is important to follow due diligence in the design, installation, and inspection of roofs and their substrates along with some related information relative to the roofing chapter of the *2004 Florida Building Code, Residential* (excluding High Velocity Hurricane Zone areas, which are covered in Chapter R44) are also included.

Although several sources were used to compile this information, a special thanks is given to:

- The Roofing Industry Committee on Weather Issues, Inc. (RICOWI) for images and preliminary results of their Wind Investigation Program and to
- Bill Zoeller, Steven Winter Associates, for images.



The 2004 Hurricane season was very active.

Characteristics of hurricanes

- Increased wind speeds (for hours)
- Wind gusts (tens of thousands of gusts)
- Slowly changing wind direction (up to 180 degrees)
- Wind-borne debris (small and large “missiles”)
- Storm surge (up to 20 feet or more)
- Waves (33 feet in open ocean)
- Extensive rainfall (up to 30 inches in 48 hours)
- Tornadoes (right front quadrant of advancing storm)
- Atmospheric pressure change

3

What is a hurricane?

General

- A hurricane is a special type of windstorm
  - Gusting, turbulent winds, changing slowly in direction, and carrying wind-borne debris
- Building design must consider:
  - Main Wind Force Resisting System (MWFRS)
  - Components and Cladding (C & C)
  - Internal pressure for buildings
  - Wind-borne debris impacts

4

Hurricane windstorm

Hurricanes consist of high-velocity winds blowing circularly around a low-pressure center, known as the eye of the storm. The low-pressure center develops when the warm, saturated air is under run and forced upward by denser, cooler air. Note: There are numerous books, papers, and articles that go into great detail about the atmospheric mechanics responsible for a hurricane. There are several website where more in-depth information can be obtained. Two such websites are: http://www.nhc.noaa.gov/ and http://www.noaa.gov/

Building designs for high-wind areas must consider the following:

- **Main Wind Force Resisting System (MWFRS)**: Florida Building Code - An assemblage of structural elements assigned to provide support and stability for the overall structure. The system generally receives wind loading from more than one surface.
- **Components and Cladding (C & C):** Florida Building Code - Elements of the building envelope that do not qualify as part of the main wind-force resisting system. Include elements such as roof sheathing, roof coverings, exterior siding, windows, doors, soffits, fascia, and chimneys.
- **Internal pressure for buildings:** The uncontrollable entry of wind into the building creates and internal pressure that, in conjunction with negative external pressures, can "blow the building apart."
- **Wind-borne debris impacts:** Effects to the building envelope from wind-borne debris that may cause internal pressure build up.

Saffir-Simpson Hurricane Scale

Category	Wind Speed Over Water			
	Saffir-Simpson Wind speed (1 min)	Florida Building Code Wind speed (3 sec)	Storm Surge (feet)	Evacuation Area
1	74 – 95	94 – 121	4 – 5	Direct coast
2	96 – 110	122 – 140	6 – 8	Coastal & low areas
3	111 – 130	141 – 165	9 – 13	Less than 5 feet
4	131 – 155	166 – 197	14 – 18	Less than 12 feet
5	155 +	198 +	18 +	Most areas

5

Table for comparisons.

- Wind speeds are clocked above most buildings.
- What's felt on the ground usually is not as strong as the maximum sustained winds measured by the National Hurricane Center.
- Here are projected sustained wind speeds at various heights in a suburban area during a Category 2 hurricane.

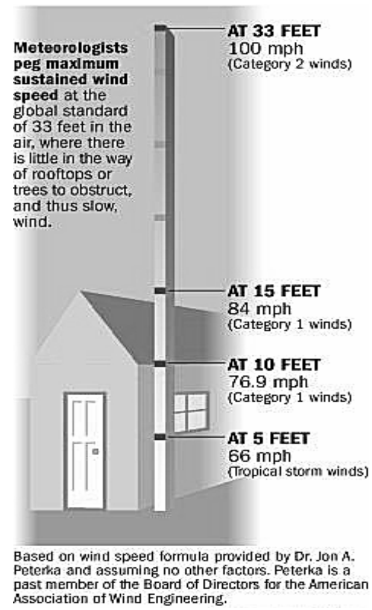
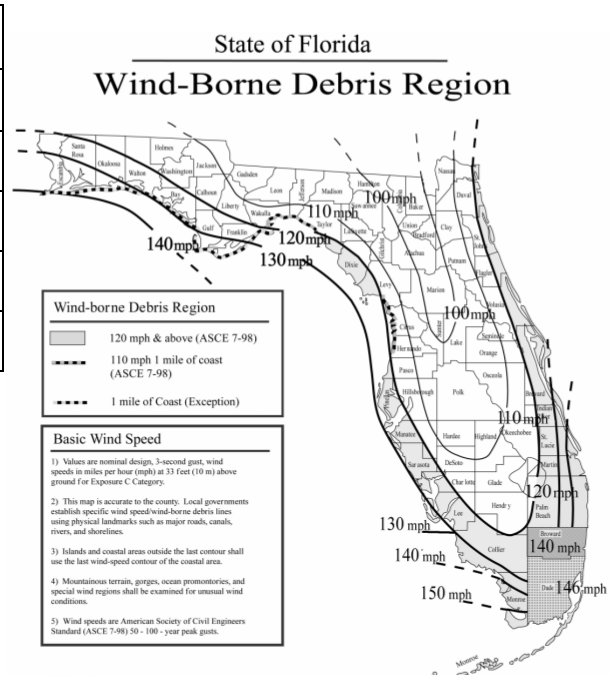


Image from: *Why Roofs Failed: a* Palm Beach Post *Special Report*. December 19, 2004. 6

Note height at which wind speed is determined.

Category	Wind (mph)
1	94 – 121
2	122 – 140
3	141 – 165
4	166 – 197
5	198 +



Determining wind speeds

A computer model generates 20,000+ years of artificial hurricane records that statistically replicate these tracks and other hurricane properties

Data from artificial records are used to develop wind risk models for specific locations

This approach was used to develop hurricane wind speed contours in the American Society of Civil Engineers (ASCE) Basic Wind Speed Map – Figure 6-1b (see the ASCE 7-98 commentary C6.5.4 Basic Wind Speed for a more in-depth analysis).

Above is the ASCE 7-98 Wind Speed Map modified for the 2004 Florida Building Code, Building (for designation of the Wind-Borne Debris Region). See Figure R301.2(4).

Major modifications to the Wind Speeds include:

Section 1620 High-Velocity Hurricane Zones—Wind Loads

1620.2 Wind Velocity (3-second gust) used in structural calculations shall be 140 miles per hour (63 m/s) in Broward County and 146 miles per hour (65 m/s) in Miami-Dade County.

Wind-Borne Debris Regions (FBC)

- Areas within one mile of the coastal mean high water line where the basic wind speed is 110 mph or greater.
- Areas where the basic wind speed is 120 mph or greater except from the eastern border of Franklin County to the Florida-Alabama line where the region includes areas only within one mile of the coast.

8

Wind-borne debris impacts cause breach in building envelope, thus causing internal pressure, or damage of connection member.

Wind-Borne Debris Regions of ASCE 7-98 were modified by Florida Statute. [Section 109(3), Ch. 2000-141, Laws of Florida]

Wind-Borne Debris Regions are defined to alert the designer to areas requiring consideration of missile impact design and potential openings in the building envelope. In Wind-Borne Debris Regions consideration of impact-resistant glazing and impact-resistant coverings is required, as an alternative to the internal pressure design.

Wind-borne debris

Image courtesy of RICOWI – Joe Wilson

9

Wind-borne debris is an important consideration in both the design and construction of a structure.

Background of the RICOWI Wind Investigation Program

- Oak Ridge National Laboratory held two workshops in 1989 devoted to identifying and discussing roof wind uplift issues, alternatives, problems, etc.
- Consensus was to form a committee (The Roofing Industry Committee on Wind Issues —RICOWI)
  - Charter approved in 1990

10

In 1989, Oak Ridge National Laboratory held two workshops devoted to identifying and discussing roof wind uplift issues and alternatives. Discussion of important technical issues included cases of roof wind damage, dynamic testing of roof systems, the importance of sample size for tests, the role of wind tunnels, air retardants and the need for acceptable procedures for ballasted systems.

There was also concern for the general lack of communication within the roofing industry as to what the problems are, what is being done to alleviate them, and how effectively technology transfer is accomplished within the roofing industry and the building community. At the conclusion of the workshops a consensus recommendation was to form a committee to address these matters. The Roofing Industry Committee on Wind Issues (RICOWI) was established and the charter approved October 1990.

- Roofing Industry Committee on Wind Issues changed to Roofing Industry Committee on Weather Issues

11

At the March 1999 meeting, the Board of Directors approved expanding RICOWI's mandate to address other weather topics and issues including hail, energy efficiency and durability effects. To reflect the broadened scope, RICOWI changed its name to the Roofing Industry Committee on *Weather* Issues, Inc.

RICOWI is funded through the generous support of its members and government and industry grants.

RICOWI / DOE / ORNL

- Groups formed to facilitate the Wind Investigation Program (WIP)
  - Includes all of the major roofing trade associations in North America
  - Identifies an event as “a windstorm with a minute sustained wind speed of 95 mph or greater when it makes landfall in a populated area of the continental U.S.”

12

Subsequent to RICOWI's formation, other concerns were raised. For example, the insurance industry conveyed their concern regarding excessive property loss from windstorms. They estimated that from 1984 to 2004 alone, hurricanes and high winds accounted for nearly 64% of catastrophic losses. In August 1992, Hurricane Andrew caused $16 billion in insured losses. A one-month period of hurricanes in 2004 resulted in more than $20 billion in insured losses.

RICOWI and the Department of Energy/Oak Ridge National Laboratory (ORNL) responded to industry involvement by entering into a cooperative Research Development Agreement (CRADA) to facilitate the Wind Investigation Program (WIP). The Program includes all of the major roofing trade associations in North America. The Program identifies an event as a "a windstorm with a 1 minute sustained wind speed of 95 mph or greater when it makes landfall in a populated area of the U.S."

Mission of WIP

- Investigate the field performance of roof assemblies after major wind storm events
- Factually describe roof assembly performance and modes of damage
- Formally report results of investigations and damage modes for sustained wind speeds

13

The Wind Investigation Program's (WIP) mission is to investigate the field performance of roof assemblies after major wind storm events, factually describe roof assembly performance and modes of damage, and formally report results of investigations and damage modes for substantiated wind speeds.

RICOWI WIP activity in 2004

- Conducted comprehensive roofing investigations of hurricane stricken areas immediately following
  - Hurricane Charley (August 13, 2004)
  - Hurricane Ivan (September 16, 2004)
- This presentation contains some of the committee’s preliminary findings
- Check http://www.ricowi.com for availability of final report

14

ORNL/Department of Energy facilitated and helped fund the training program for wind investigators and has been working with private industry to accelerate the acceptance of more energy-efficient and durable roofing systems.

In 2004, comprehensive roofing investigations of hurricane-stricken areas were taken following Hurricanes Charley and Ivan. This presentation contains some of the WIP's preliminary findings, along with the thoughts of others in the roofing-related trade. The method of obtaining a copy of WIP's final report is listed on their web site http://www.ricowi.com

Flying debris and downbursts…

Significant structural damage made roof analysis difficult at best.

Images courtesy of: RICOWI – Jerry Vandewater

As can be imagined, it is sometimes hard to determine exact causes of damage. For example, downbursts and flying debris like this hammer in side of house--that did not belong to owner of home--and this ornamental glass ball that caused window damage to front windshield of motor home.

Images courtesy of: RICOWI – Jerry Vandewater

It is important to understand that the RICOWI WIP team did not try to explain and/or evaluate roofs where there was evidence of significant structural damage.

Failure due to wind pressure

(and maybe poor installation)

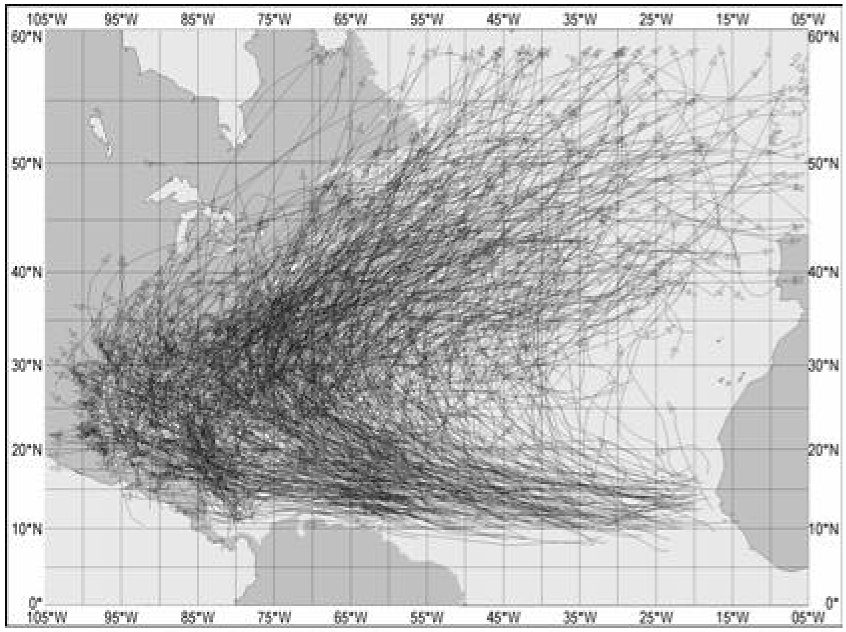
For instance, the roof on this structure would have been evaluated but...

Image courtesy of: RICOWI – Jerry Vandewater 18

...this kind of failure due to wind pressure was not investigated. At least it appears the hurricane clips worked…but that's little consolation to the homeowner.

So, who *really* is at risk?

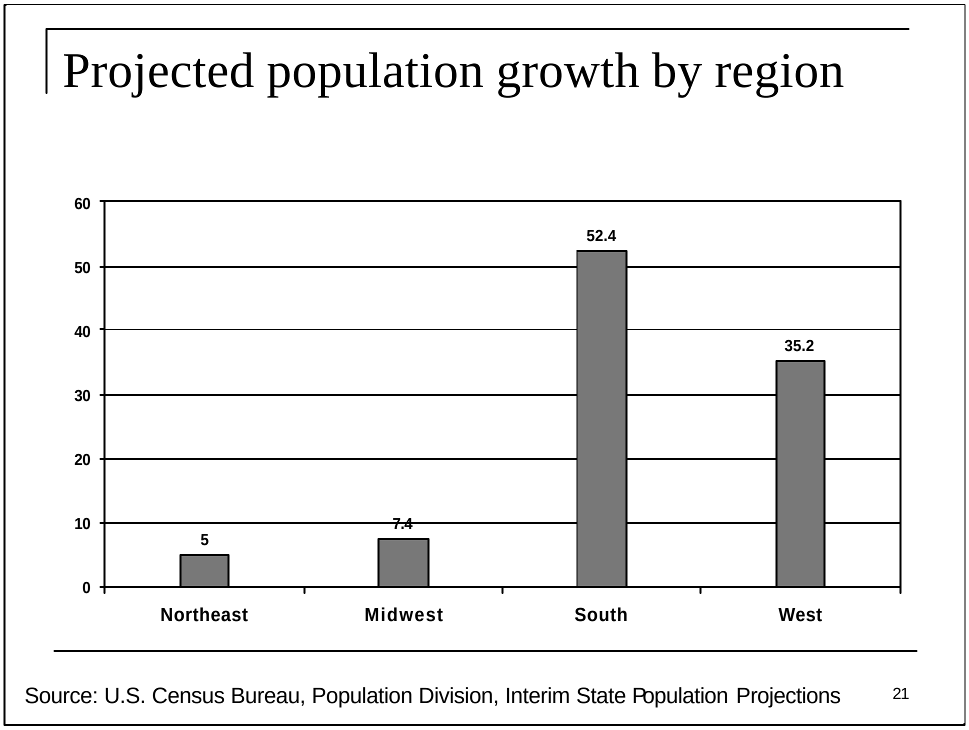
From this graphic it looks like Florida has been left pretty much unscathed for over 50 years.



NORTH ATLANTIC TROPICAL STORMS AND HURRICANES, 1886 -2000 (1013 STORMS)

However, looking at this graphic illustrating the paths of all tropical storms and hurricanes from 1886 to 2000, we should think otherwise.

Map provided by National Hurricane Center in 2002.



In addition, the U.S. Census Bureau, Population Division Interim State Population Projections, projects that the population in the South will increase by 52.4 percent from 2000 to 2030 (greater than any other region).

Florida's population growth

- Florida’s population as of the 2000 census was approximately 16 million
- By 2030 Florida is projected to have over 28 million residents, with over 27% being age 65-and-older

Florida alone is projected to increase from almost 16 million residents in 2000 to over 28 million residents by 2030. Florida, already 1st in the percentage of population age 65-and-older ($\cong$ 18%), is projected to remain 1st (27%) in the 65-and-older category in 2030.

Image from: *Why Roofs Failed: a* Palm Beach Post *Special Report*. December 19, 2004.

23

The 2004 hurricane season was memorable for a number of reasons. Probably, few will soon forget the Blue Roof Syndrome where, in some cases, entire apartment complexes or developments had their roofs tarped in blue due to roof damage. In this case it is an apartment complex in West Palm Beach (October 2004).

How many of Florida's residents will be able to install "blue roofs"? Shouldn't we try to do everything possible to avoid this scenario?

[Notice the lack of overhang at gables.]

Aerodynamics

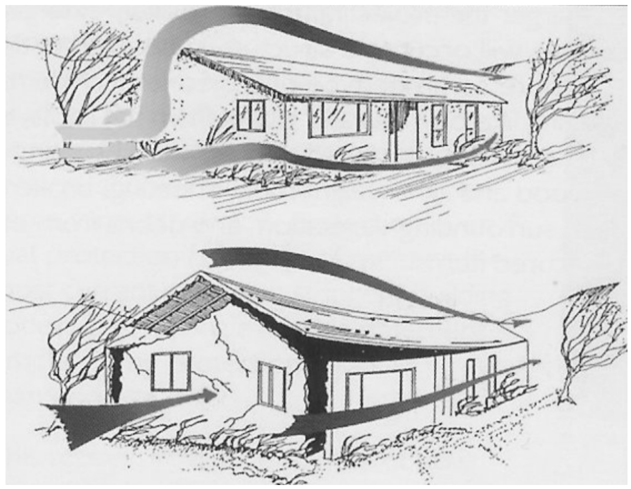


Image courtesy of: RICOWI - Jim McDonald

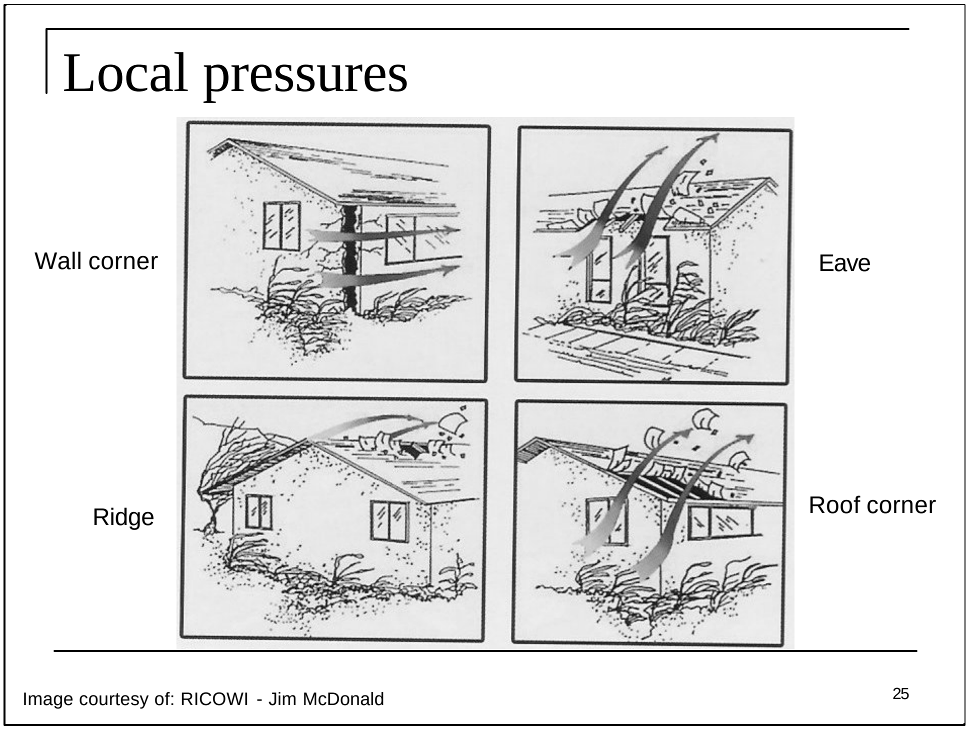
24

Before looking at damage-specific slides, let's look at the aerodynamics of the wind itself.

Main Wind Force Resisting Systems experience external pressure and forces:

- Affect building surfaces
- Windward wall experiences inward-acting pressures
- Leeward and side walls and roof experience outward-acting pressures
- Aerodynamic effects can cause collapse of surface

What points of the roof are most likely to experience stresses and failures? Why?



Because of the acceleration as air flows past sharp corners, very high suction pressures develop at wall corners, eaves, ridges and roof corners.

The highest wind pressures on roofs occur at roof corners—particularly if wind is coming in at an oblique (indirect) angle at the corner.

Components and cladding experience general and local external pressures:

- Local pressures
- Pressure changes at sharp edges
- Pressure changes cause lift turbulence and localized high positive and negative pressures
- Aerodynamic effects depend on the shape of the building or structures
- Aerodynamic effects are complex and can be defined only through experiments in wind tunnels or in full scale

Internal pressure

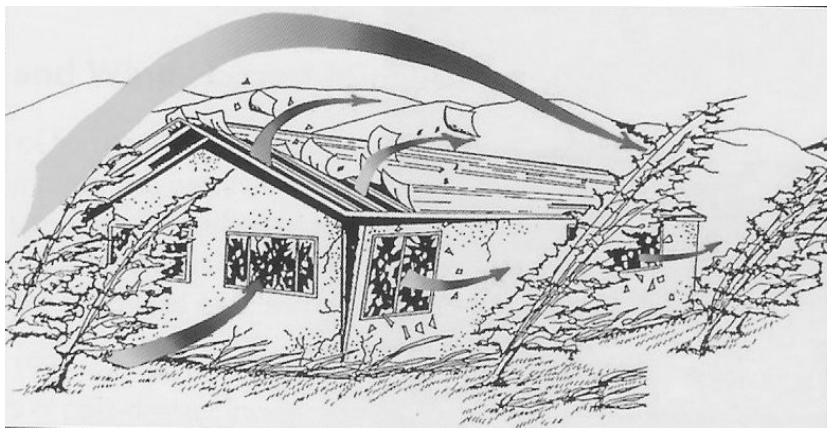


Image courtesy of: RICOWI - Jim McDonald

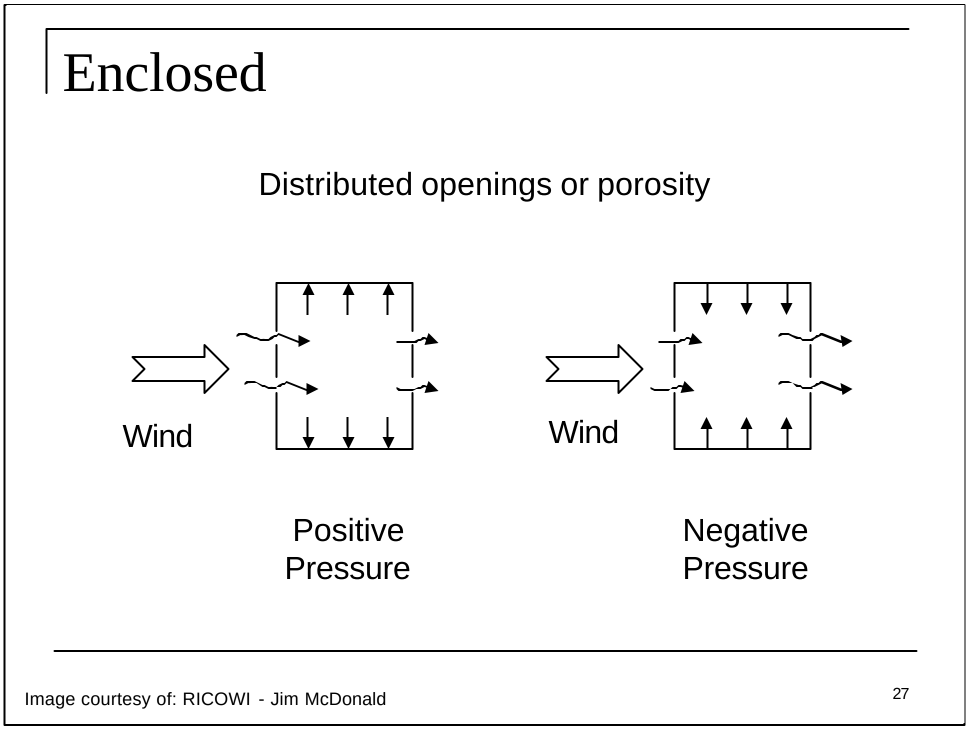
26

- Openings or natural porosity in a building allow internal pressures to develop.
- External and internal pressures combine to induce high outward acting pressures on leeward and side walls and roof.
- Openings as small as 1 percent of a wall area can produce full internal pressurization.

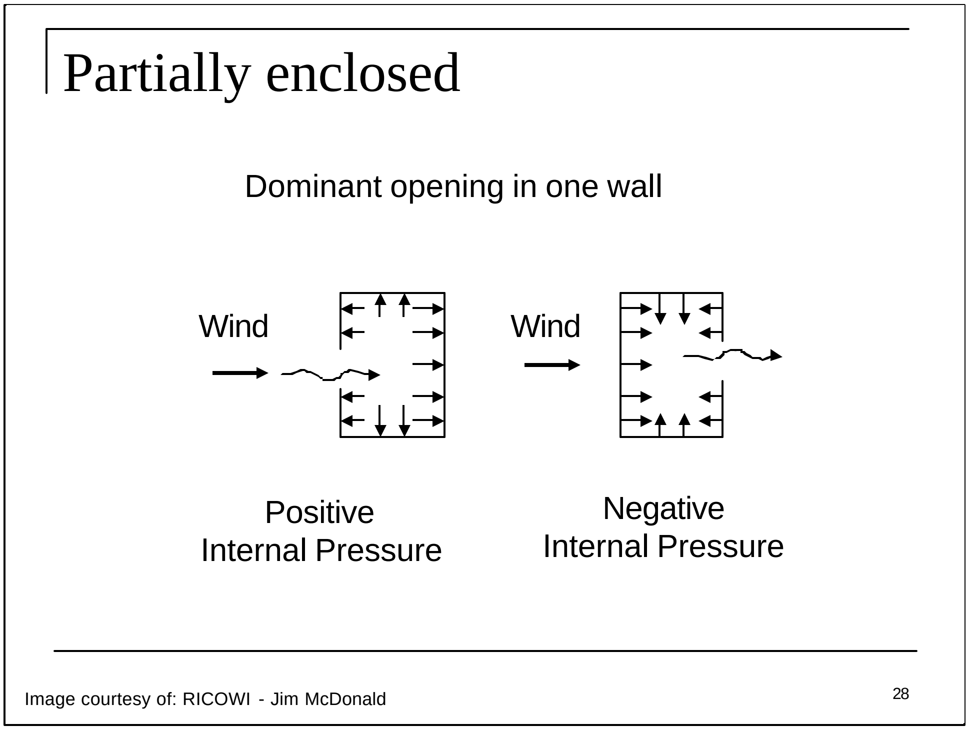
Even without specific openings, a small amount of internal pressure exists in most buildings because of permeability. It is similar to blowing up a balloon—wind getting in and being a positive pressure. Internal pressure is a problem that has to be dealt with.

Internal pressures are therefore caused by permeability in a building and/or when wind enters the building through its dominant opening.

The magnitude of internal pressure depends on whether the building is "enclosed," "partially enclosed," or "open," as defined by ASCE (American Society of Civil Engineers) 7-98.



- An enclosed building can have openings.
- Distribution and relative size determine classifications, i.e. no dominant opening in one wall.
- If a building is not partially enclosed, it is classified as either enclosed or open.
- Size of openings in walls or natural porosity limit the magnitude of internal pressure.
- Internal pressure can be either positive or negative.



A partially enclosed building is defined as one where a dominant opening exists in one wall.

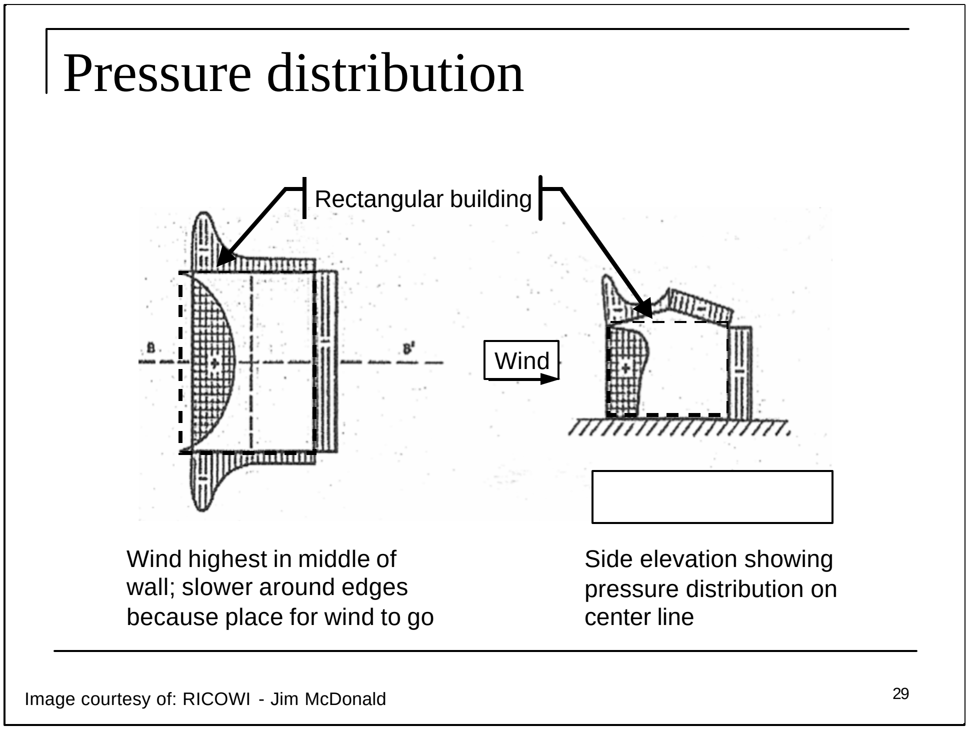
- Size of openings in other walls and roof are limited so that relatively high internal pressure can develop inside the building.
- This situation results in the highest possible internal pressure.
- If external pressure at the opening is positive, the internal pressure will be positive.

Dominant opening on windward wall results in positive internal pressure.

- The internal pressure pushes toward the interior wall surface.

Dominant opening in leeward or side wall or roof results in negative internal pressure.

- The internal pressure pulls away from the interior wall surface, like letting air out of a balloon.



Approximate distribution of mean wind pressure on a building in open terrain.

If the roof is flat, wind loads on the roof are a step function, highest at the windward side.

Pressures are a function of wind velocity: the taller the building, the greater the velocity.

Oblique wind

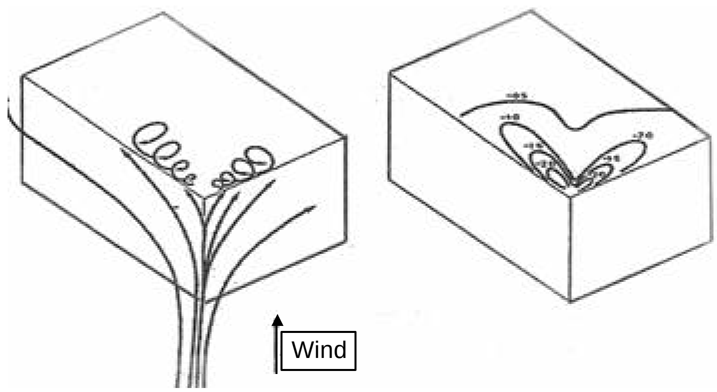


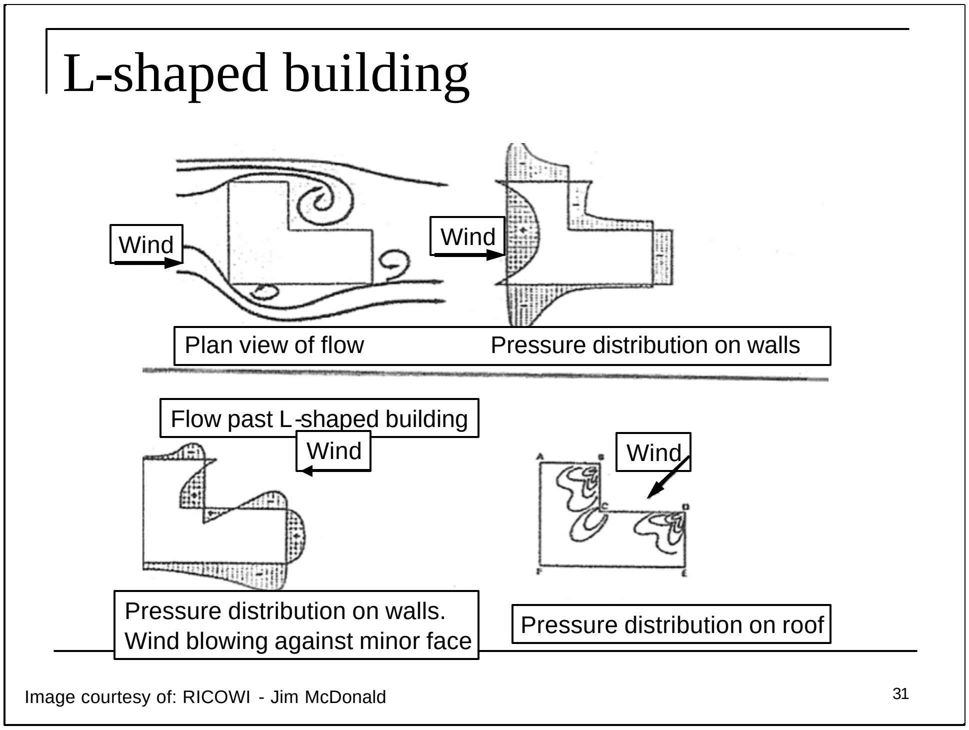
Image courtesy of: RICOWI - Jim McDonald

30

Wind flows upward and over each wall. As it lifts over the edge of the roof it curves into a spiral to form strong vortices along the roof edges.

Very high local suctions (negative pressures) occur on that part of the roof under the influence of the vortices. This can be seen in scouring on a built-up roof, in which the gravel has been removed by the wind along the roof edges.

Most damage is caused by wind uplift (vertical), suctional, and torsional (twisting) forces. The wind uplift pressures on a roof vary depending on roof/building height, roof slope, location (oceanfront or inland), and roof style.

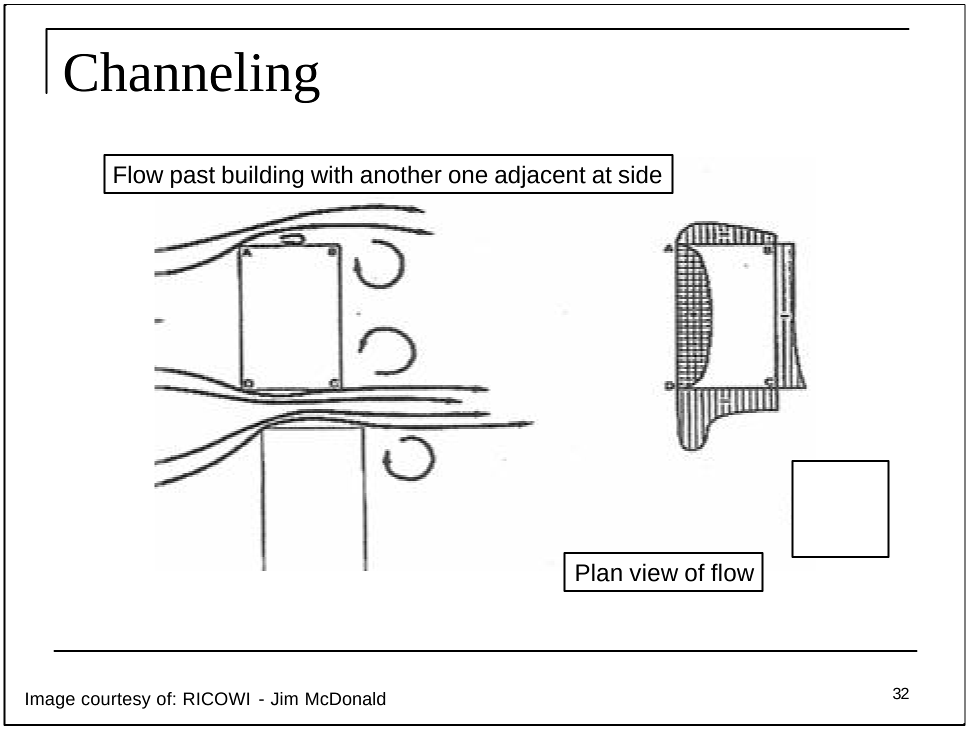


Note that the wind stream generates uplift as it divides and flows around a structure. The wind follows the longest path, which is normally over the roof, then speeds up to rejoin the wind stream following the shorter distance, which is usually around the walls. As the wind speeds up across the roof, the pressure drops thereby generating uplift. The roof, in effect, tries to "take off" from the rest of the building. Uplift is greatest at the corners of the roof.

In L-shaped buildings (above), wind blowing against major face, as shown in upper sketch, the flow diverts around the building in the usual way but is drawn into a large eddy in the recessed corner.

A cornering wind, as shown in the lower sketch, generates vortices over the roof from each windward corner.

The flow tends to channel into the reentrant corner creating a large updraft there and consequently high suctions on the roof.



Channeling between the two buildings results in pressures that are highest near the windward edge of the wall.

The effect shows up most dramatically in gable end wall failures of houses.

Wind and structural interaction

- Summary of the effects of wind on buildings:
  - Windward walls and steep-sloped roofs are acted on by inward-acting or positive pressures.
  - Leeward walls and steep- and low-sloped roofs are acted on by outward-acting or negative pressures.
  - Pressure changes at sharp edges and at points where the building geometry changes
  - Localized suction or negative pressures at eaves, ridges, and the corners of roofs and walls are caused by turbulence and pressure changes. These pressures affect load on components and cladding.

33

Summary of the effects of wind on buildings.

Image courtesy of: Bill Zoeller

34

Let's look at roof types.

Although hip roofs have been reported to have fewer problems, roof damage still occurs.

Hip roofs are believed to be less prone to damage than gable roofs because:

- They slope in four directions
- The sloping faces enhance the performance of the roofing material
- They generate less uplift and are structurally better braced
- They laterally brace the primary roof trusses, or rafters, and support the top of the end walls of the home against lateral wind forces
- They eliminate the hinge formed between a gable end and a gable-end wall

Image courtesy of: Bill Zoeller

35

An example of gable roof damage

Wood-frame gable ends of roofs can be failure-prone, except when properly braced. In many instances gable-end failure seems primarily attributable to poor or non-existent bracing between gable-ends and the rest of the structure. The use of structural outlookers rather than ladder-type framing can also help. These generally cantilevered 2×4s oriented edge-wise at roof sheathing joints extend outward from the first interior trusses or rafter over "dropped" gable-end wall framing. Secondary bracing installed between trusses can also increase lateral support.

In addition, the nailing pattern used on roof sheathing needs to be designed for both shear and uplift loads.

Aerial shots of flat roofs in Port Charlotte

Internal pressurizations of structures, often times commencing at soffit / overhangs of buildings

Image courtesy of: RICOWI, Jerry Vanderwater

36

An example of damage to flat roofs

Many flat and low-slope roof systems show damage primarily at roof corners.

Image courtesy of: RICOWI – Jerry Vandewater

37

Different roof coverings also suffered damage…including concrete tile…

Image courtesy of: Bill Zoeller

38

Clay-based tile…

Image courtesy of: Bill Zoeller 39

Metal…

Image courtesy of: Bill Zoeller

40

Shingles…

Wood

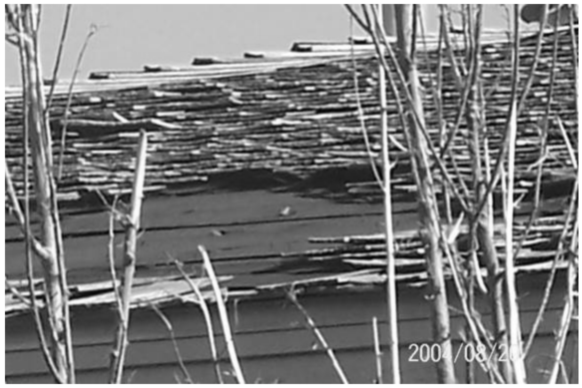


Image courtesy of: RICOWI – Joe Wilson

41

…and wood shakes.

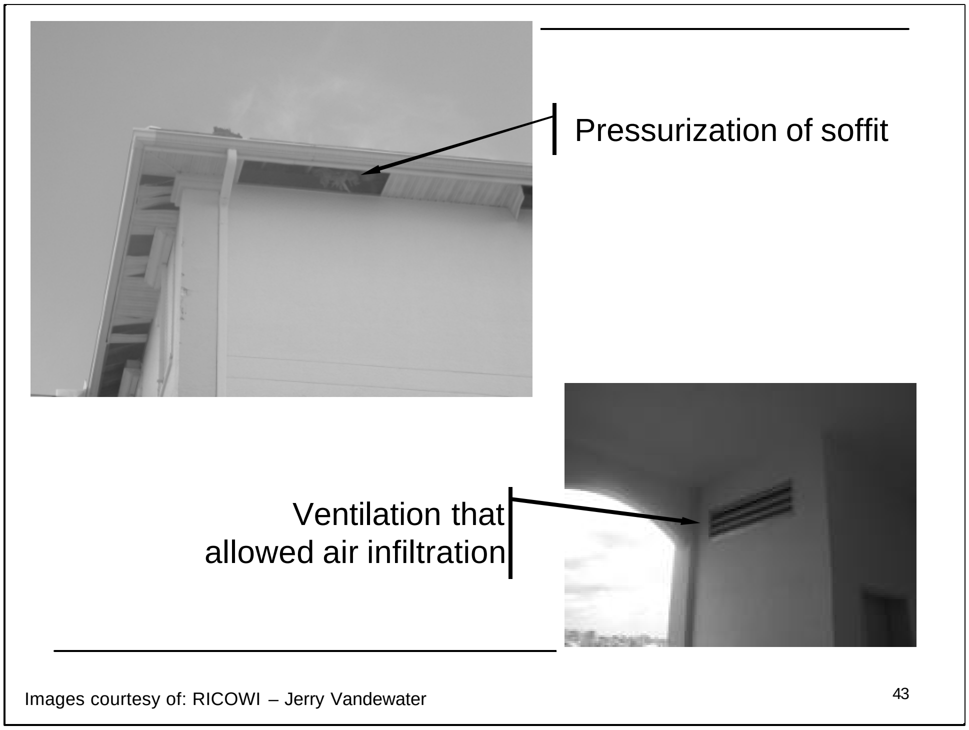
Now, let's investigate some of these roof coverings.

Images courtesy of: RICOWI – Jerry Vandewater

Concrete tile—mechanical attachment

- Pressurization of the building—soffits blown out
- Entire roof "survived" except hips and ridges
- Set trim tiles only in mortar
- Field tiles might have "survived" but tiles damaged

Why is the photograph in the middle of the slide important?



Concrete tile—mechanical attachment

It was the pathway for air infiltration…which resulted in the pressurization of the soffit.

Mortar—wrong location

Tiles on this project created damage on lower parking area. Unable to determine if the damage was caused by the storm or from the clean-up.

Images courtesy of: RICOWI – Jerry Vandewater

44

Concrete tile—mortar attachment

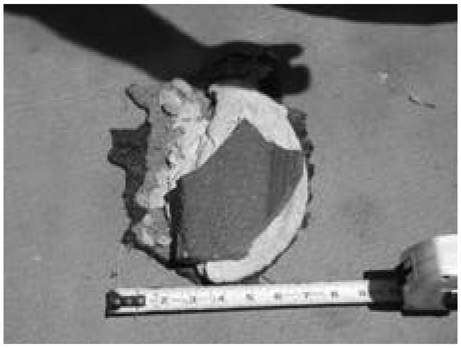
Mortar in wrong location; wind got underneath, resulting in photo on lower left.

Problems with bond of tile to mortar and mortar to underlayment

Problems with mortar at hips and ridges

Images courtesy of: RICOWI – Jerry Vandewater
45

Concrete tile—mortar attachment



Mortar manufacturer's instructions call for #10 trowel of mortar

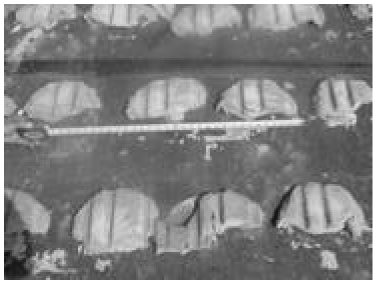
Age of underlayment may come into play

Underlayment to deck—bonding issue

Images courtesy of: RICOWI – Jerry Vandewater

Concrete tile—mortar attachment

There are specific requirements for type of mortar and placement.



Mortar installation
in Punta Gorda

- Windward face of roof
- Notice hip and ridge

Images courtesy of: RICOWI – Jerry Vandewater

47

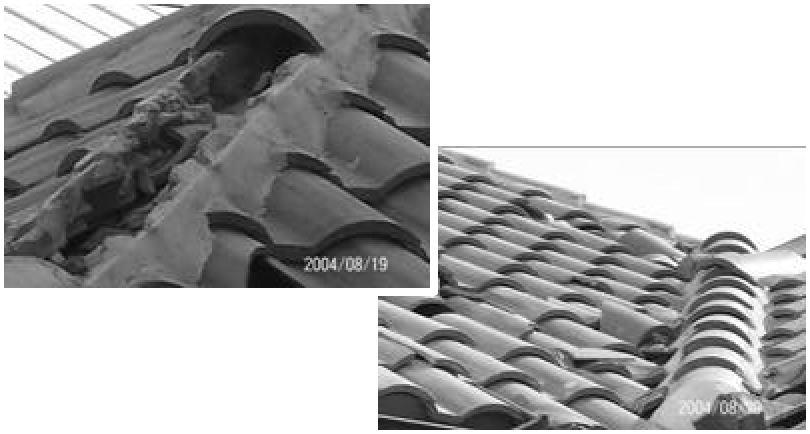
Concrete tile—mortar attachment

Improper mortar patty placement and size.

The eave portion appears to have eave closures in lieu of mortar.

The expertise of the individual(s) mixing and applying the mortar on site is of utmost importance.

Some hip barrels lost from mortar; debris damaged some field pieces.



Images courtesy of: RICOWI – Joe Wilson

Concrete hip/ridge pieces loosened from cement.

Field damage from hip/ridge debris.

Steep slope: concrete tile

- Mortar attachment
  - Method used on older homes, prior to 1997
  - Method used on most homes with tile in Punta Gorda
  - Many variables in this system, from materials to workmanship, that can come into play
  - Tough to evaluate where performance failed in the system

Mortar-attached tile systems

- In many cases, hips that were still in place had loose trim tiles when lifted—no form of securement beyond the beads/strips of mortar (which appeared to be mixed at site by contractors)

50

Note that tile roofs 6:12 and over are required to be mechanically attached. Also, not every tile is the same.

Mortar-attached tile system

- Numerous failure modes including:
  - Mortar paddy too small
  - Improper placement of paddies
  - Lack of adequate contact to tile or underlayment
  - Evidence of tiles that lost bond to mortar and mortar that lost bond to underlayment

51

Note that tiles should be wet when installed in mortar.

- Lack of material
- Did not make contact to tile

- Single component adhesive requires compression to make bond
- Not enough adhesive results in lack of bond to tile and underlayment

Images courtesy of: RICOWI – Jerry Vandewater

52

Concrete tile—adhesive set systems

In this case essentially loose-layed tile on roof, held by gravity and friction.

Options:

- 1- or 2-component systems (perform differently)
  - Relies on compression—tile has to be forced on
  - Two different compounds—expand and form to tile with expansion of foam (most now polyurethane foams)
- Multiple path configurations
  - Location very important

Concrete tile—adhesive set systems

Location of adhesive very important.

A lot of impact damage in this case.

Keep in mind that wind-borne projectiles are a major factor in home damage and destruction during a hurricane. The penetration of the building envelope (through the loss of doors—primarily garage and glass—and windows) can allow the buildup of internal air pressure that acts to lift the roof and push out the side walls. Wind-borne debris (especially from roofing materials) can contribute to a significant portion of this damage. Flying debris from vegetation, other construction material, and utility equipment can also cause a lot of damage.

Adhesive set system—2-component

Image courtesy of: RICOWI – Jerry Vandewater

54

Concrete tile—adhesive set systems

Photo taken at mouth of harbor. This photo verifies that the system could perform well. Perhaps large buildings helped buffer wind impact?

Adhesive-attached systems (tile)

- Single- and two-component adhesive systems
  - Each of which has a well-defined installation requirement
  - Only able to analyze a few structures
  - Those installed properly appeared to work

55

Soffit and
framing damage

Flat tiles nailed with 0 to 1 nails

Images courtesy of: RICOWI – Joe Wilson

56

Part of rake pulled off, which led to pressurization.

Steep slope: concrete tile

- Mechanical attachment methods allowed
  - Single ring shanked nail—outlined in the FRSA/TRI Installation Guide to be A641 Class 1 Nail with 19-21 rings per inch (for up to 130 mph)
  - Single #8 Quikdrive screw per same manual

57

2004 Florida Building Code, Residential

- R905.3.1 Deck requirements
- R905.3.2 Deck slope
- R905.3.3 Underlayment
- R905.3.7 Application
- R905.3.8 Flashing

58

The following Sections of the *2004 Florida Building Code, Residential* may be of particular interest with respect to concrete and clay tile:

R905.3.1 Deck requirements. Concrete and clay tile shall be installed only over solid sheathing except where the roof covering is specifically designed and tested in accordance with Chapter 16, *Florida Building Code, Building* to be applied over structural spaced structural sheathing boards.

R905.3.2 Deck slope. Clay and concrete roof tile shall be installed on roof slopes in accordance with the recommendations of FRSA/RTI 07320.

R905.3.3 Underlayment. Unless otherwise noted, required underlayment shall conform with ASTM D 226, Type II; ASTM D 2626; ASTM D 1970 or ASTM D 6380 mineral surfaced roll roofing.

R905.3.7 Application. Tile shall be applied in accordance with this chapter and the manufacturer's installation instructions, or recommendations of the FRSA/RTI 07320 based on the following:

Attachment. Clay and concrete tiles shall be fastened in accordance with FRSA/RTI Installation Manual 07320.

R905.3.8 Flashing. At the juncture of roof vertical surfaces, flashing and counter flashing shall be provided in accordance with this chapter and the manufacturer's installation instructions or recommendations of the FRSA/RTI 07320 Manual.

Other recommendations

- Supplemental instructions for hip and ridge attachment sections of the FRSA/RTI "Concrete and Clay Roof Tile Installation Manual" – 3rd Edition are available for use by authorities having jurisdiction
- Available April 2005

59

According to the document…

These recommendations were developed after surveying the recent hurricanes and with input from the code, roofing and tile manufacturing community. They are designed to further clarify the current installation procedures as they pertain to the specific roof tile systems (mechanically fastened, adhesive-set, mortar-set).

The recommendations provide for only products approved by the Florida Building Code and verified by third party independent FBC approved laboratories, to determine the wind uplift limitations of the various hip and ridge attachment methods or by installation methods currently recognized in the HVHZ (High Velocity Hurricane Zone) section of the FBC.

A joint sub-committee consisting of members from the FRSA (Florida Roofing, Sheet Metal and Air Conditioning Contractors Association, Inc.) and the TRI (Tile Roofing Institute) drafted these recommendations and they were approved by consensus by the FRSA Roof Tile Committee.

These supplemental recommendations can be found on the Web at

http://www.dca.state.fl.us/fbc/Hurricane%20Research%20Advisory%20Committee/FRSA_TRI%20Roof%20Tile%20Report/Hip_and_Ridge_Installation_Final-Rev_4-06-05.pdf

Undamaged standing seam roof

Image courtesy of: RICOWI – Joe Wilson

60

Attached to plywood; undamaged in Boca Grande.

Standing seam metal came off from screwed clips, which pulled and tore loose from stapled plywood.

Structural damage

Images courtesy of: RICOWI – Joe Wilson

Overhanging deck and truss failure initiated release of standing seam roof.

Images courtesy of: RICOWI – Joe Wilson

62

Overhangs were scabbed on.

Clips were used.

Very exposed standing seam roof without damage.

Images courtesy of: RICOWI – Joe Wilson

Impact damage to standing seam metal roof

Scattered debris from adjacent roof

Images courtesy of: RICOWI – Joe Wilson

64

5 V-ribbed metal that did well…a lot of fasteners in this system

Image courtesy of: RICOWI – Jerry Vandewater 65

Metal roofing

Properly installed metal roofs, although the sample was small, appeared to do quite well. This building is in the center of Punta Gorda.

Thru-fastened metal roof principally damaged by debris, not by wind.

Image courtesy of: RICOWI – Joe Wilson

66

Metal roofing

Typical to see soffit damage.

Damaged wind screens gave indication of how much wind.

Thru-fastened panel lifted and detached at seam but remained on roof.

Image courtesy of: RICOWI – Joe Wilson

67

No evidence of screws in seam.

More thru-fastened steel

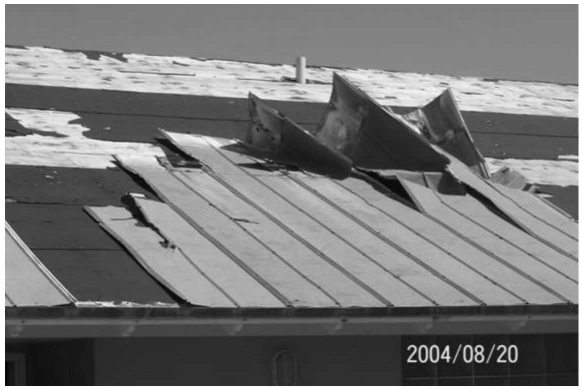
Attached to plywood—screws 6 in. o.c.

Image courtesy of: RICOWI – Joe Wilson

68

Boca Grande

Old 5V crimp



- Insufficient number of fasteners (18 in. o.c.) in rusting metal
- Applied to inadequate framing/construction

Image courtesy of: RICOWI – Joe Wilson

69

Thru-fastened 5V crimp

Panels were adequately fastened to 1× 4 stringers, but the stringers were attached to the plywood with only 6d nails, 12 in. o.c.

Image courtesy of: RICOWI – Joe Wilson

70

The battens came off with the panels.

Thru-fastened 5V crimp

- Panels fastened to 1 × 4 stringers
- The stringers were attached to the plywood with 4d nails, 24 in. o.c.

Image courtesy of: RICOWI – Joe Wilson

71

Sanibel

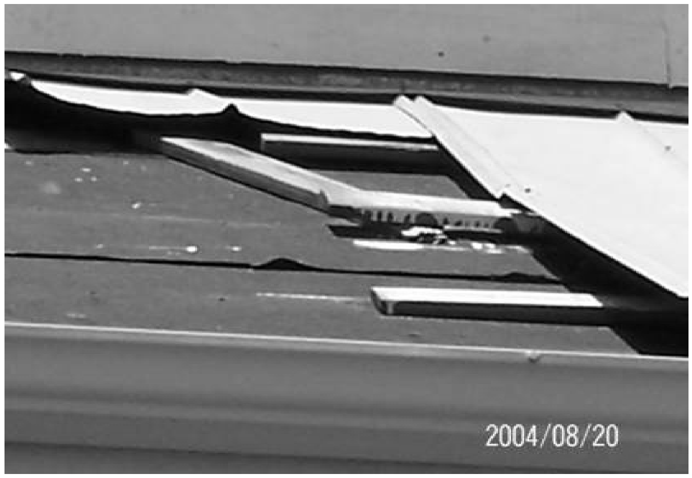


Image courtesy of: RICOWI – Joe Wilson

72

Photo shows close-up of metal roof from last slide.

- Nails used were too small
- Nail patterns inconsistent in some cases

Aluminum shingles which unlocked, then pulled off, or tore from, nails.

Images courtesy of: RICOWI – Joe Wilson

73

Boca Grande:

- Lap from the front
- Lock mechanism did not hold
- Fascia metal sometimes deformed—gave way, which then precipitated failure

Interlocking steel shingle that unlocked from edge metal and clips.

Images courtesy of: RICOWI – Joe Wilson

74

- One screw per clip
- Many roofs had two screws per clip

Metal roofing

- Only able to inspect a few metal roofs
  - The 5-V-ribbed flat metal roof systems that had fastening every 6 inches up the roof system appeared to perform.

Metal roofs

- Post-Andrew metal roof designs and installations performed very well.
  - Exceptions were usually isolated to:
    - Installation problems
    - Internal pressurization from openings, typically created by failed accessories such as overhead doors, windows, doors, etc.

77

Metal roofs

- Standing seam roof failure mode
  - On metal supports, failure was almost always the clip separation from the panel seam.
  - This failure mode emphasizes the importance of the type of seam and the seaming operation.

78

Metal roofs

- Most observed metal roof failures, not associated with a door failure and internal pressure increase, started at the eave or rake edge and progressed up towards the ridge.
- Poor eave or rake details, such as gutter attachments and flashings were the weak point and where the failure of the roof initiated.

Metal roofs: overview of findings

- When standing seam roofs were installed over wood substrates, plywood appeared to be better than OSB with regard to screw pullout.
  - Fastener type and length can be a major factor in this type of roof application.
  - Appropriate design loads for fasteners, taking into account actual substrate, must be used.

80

Metal roofs: overview of findings

- Aluminum roofs appeared to have had a higher failure rate than steel roofs in the observed areas—not statistical, but observations.

81

Metal roofs: overview of findings

- Soffit panels were easily blown away.
  - Even in well-designed newer metal roof installations.
  - More attention to soffit design and installation is recommended.
  - Hip flashing appeared to suffer frequent failure or partial failure, even in otherwise well-performing metal roof installations.

82

Metal roofs: overview of findings

- There was a high failure rate of retrofit metal roofs installed over both metal and wood-shingled roofs.
  - The eave or rake edge attachments were also suspect in this type of construction.

83

See R905.4 of the *2004 Florida Building Code, Residential* to view sections related to metal roof shingles and Section R905.10 for sections related to metal roof panels.

Related to metal roof shingles, the following section may be of particular interest:

> **R905.4.3 Underlayment.** Underlayment shall comply with ASTM D 226, Type I or Type II or ASTM D 1970.

Related to metal roof panels, the following sections may be of particular interest:

> **R905.10.2.1.** Underlayment shall be installed as per manufacturer's installation guidelines.
>
> **R905.10.4 Attachment.** Metal roofing shall be installed in accordance with this chapter and the manufacturer's installation instructions. Metal roofing fastened directly to steel framing shall be attached by approved fasteners. The following fasteners shall be used:
>
> 1. Galvanized fasteners shall be used for galvanized roofs.
> 2. Hard copper or copper alloy or three hundred series stainless steel fasteners shall be used for copper roofs.
> 3. Aluminum-zinc coated fasteners are acceptable for aluminum-zinc coated roofs.
> 4. Stainless steel fasteners are acceptable for metal roofs.

Asphalt shingles installed under solar system, and attached with 4 nails, came loose.

Image courtesy of: RICOWI – Joe Wilson

84

- Roofed with 5 types of composite shingles, some under-exposed or without seal stripping
- Both staples and nails used as fasteners

Images courtesy of: RICOWI – Joe Wilson

85

- Some shingles, even with 6 nails, tore loose.
- However, some of these nails were in the seal strip.
- There was evidence of attic pressurization.
- Plywood stapled to the trusses didn't improve the situation.

Images courtesy of: RICOWI – Joe Wilson

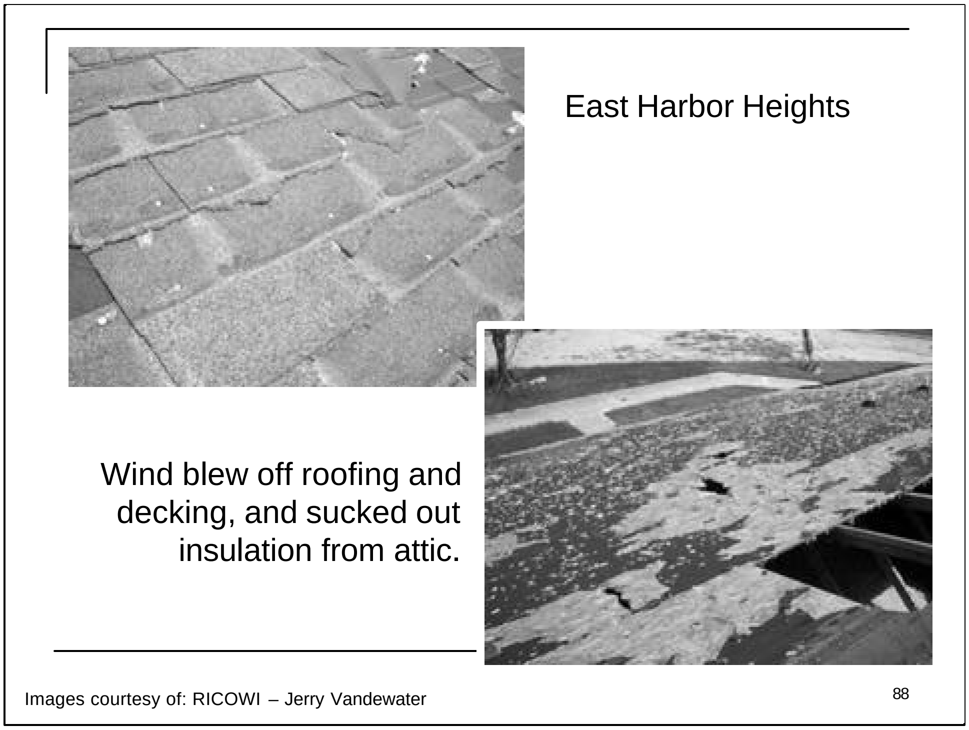
86

Captiva

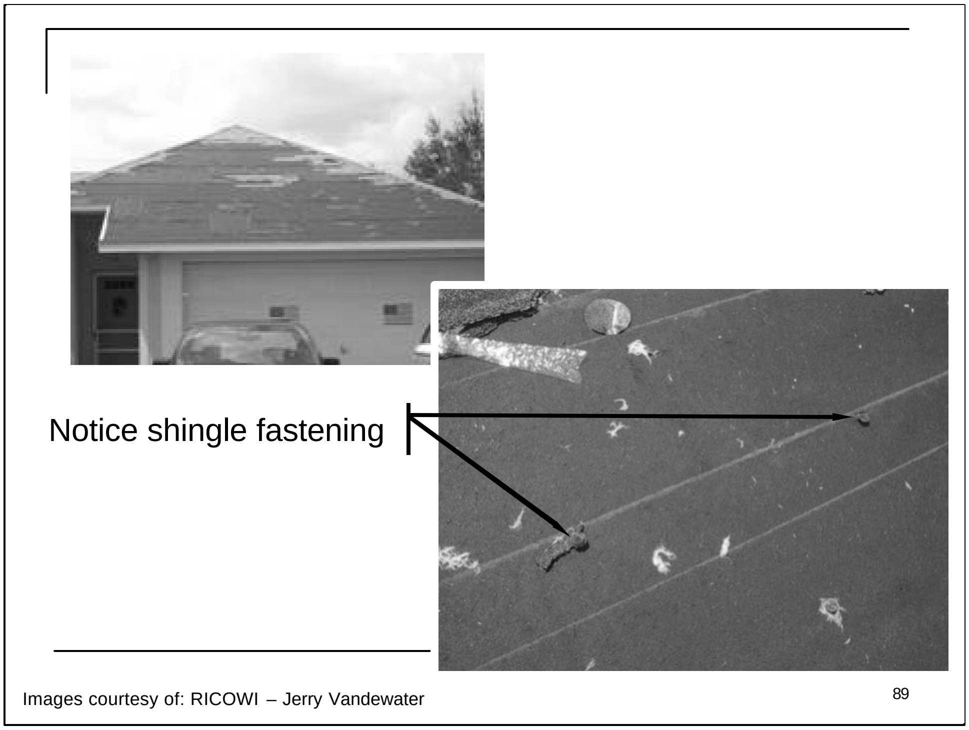
- Lack of proper fasteners

Images courtesy of: RICOWI – Jerry Vandewater

87



Other things going on—more than just roofing material problem.



- Rusty nails
- A lot of nails still in place
- Shingles pulled off

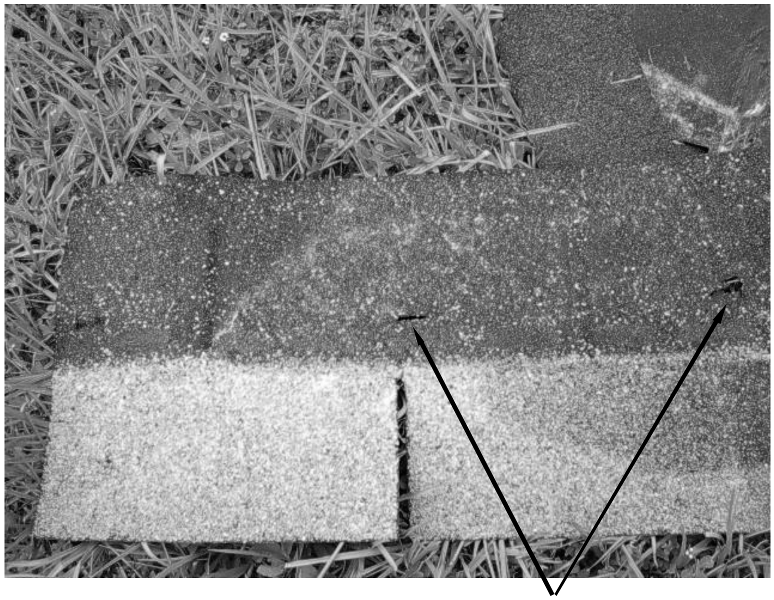


Image courtesy of: RICOWI – Jerry Vandewater

90

Staples pulled through.

Note that staples are no longer allowed.

12-year-old 3-tab shingles tore loose from 4 staples per piece.

Image courtesy of: RICOWI – Joe Wilson

91

Many of the older roofs used 3-tab shingles that were stapled.

Shingles tore loose from 6 nails placed in seal strip.

Images courtesy of: RICOWI – Joe Wilson

Placing the nails in the seal strip is a less-than-optimal location. All dimensional shingles have nail lines.

By the way...RICOWI WIP investigators did see shingles that worked—especially newer shingles and architectural shingles.

Composite shingle roof—some hip/ridge loss. Nailed with 6 nails per shingle.

Image courtesy of: RICOWI – Joe Wilson

93

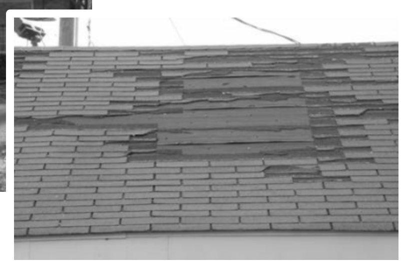
In higher wind areas, newer shingles with six nails had less damage on hips or ridges.

Hip and ridge loss on home protected by wooded areas.

Image courtesy of: RICOWI – Joe Wilson

94

4 nails per 3-tab shingles. Not sealing at tabs.



Images courtesy of: RICOWI – Joe Wilson

95

Neighbors: separated by age

1 month old

10 years old

Images courtesy of: RICOWI – Joe Wilson

96

Neighbors: design difference

Hip versus
gable application

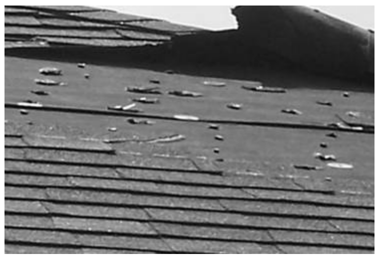
Images courtesy of: RICOWI – Joe Wilson

97

The hip roof only had minor damage on the hips.

Neighbors

Some ridge pieces tore from nails.



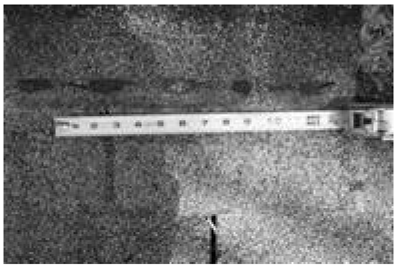
Field loss—6 nails placed in seal strip

Minor hip/ridge loss

Images courtesy of: RICOWI – Joe Wilson

More neighbors

Only hip loss with 6 nails



Using 4 to 6 staples—and placing them in seal strip—caused loss

- Hip/ridge and field loss from inconsistent nailing
- 4 to 6 nails and location

Images courtesy of: RICOWI – Joe Wilson

99

Shingle tabs lifted and tore from 6 nails per piece.

Images courtesy of: RICOWI – Joe Wilson

100

Here's a hip roof with damage.

3-tab roofing

- In general, the older styles of 3-tab roofing were found on homes built prior to the 1997 wind code and didn't appear to perform as well
- Not able to determine if age of materials came into play but lack of ability for the shingles to remain even partially intact indicated lack of uplift resistance

101

Re-roof over 3-tab

- In general, did not perform well—new layers often gone
- Even with the new architectural shingles, when installed over older 3-tab dimensional, did not work
- In many cases the length of the fasteners used were not of sufficient length to adequately penetrate the substrate

102

Note that the Reroofing Section (R907) in the *2004 Florida Building Code, Residential* is Reserved.

Architectural shingles

- Appeared newer installations did have some successes
- Many appeared to have been installed within the last few years
- Not able to determine if shingle age played a role in performance

103

2004 Florida Building Code, Residential

- R905.2.3 Underlayment
- R905.2.5.1 (under R905.2.5 Fasteners)
- R905.2.7.2 Underlayment and high wind
- R905.2.8.1 Base and counter flashing
- R905.2.8.6 Drip edge

104

See Section R905.2 of the *2004 Florida Building Code, Residential* to view Sections related to requirements for roof coverings related to asphalt shingles.

The following sections may be of particular interest:

R905.2.3 Underlayment. Unless otherwise noted, required underlayment shall conform with ASTM D 226, Type I or Type II, or ASTM D 4869, Type I or II. Self-adhering polymer modified bitumen sheet shall comply with ASTM D 1970.

R905.2.5.1 The nail component of plastic cap nails shall meet ASTM A 641, Class I or an equal corrosion resistance by coating, electro galvanization, mechanical galvanization, hot dipped galvanization, stainless steel, nonferrous metal and alloys or other suitable corrosion resistant material.

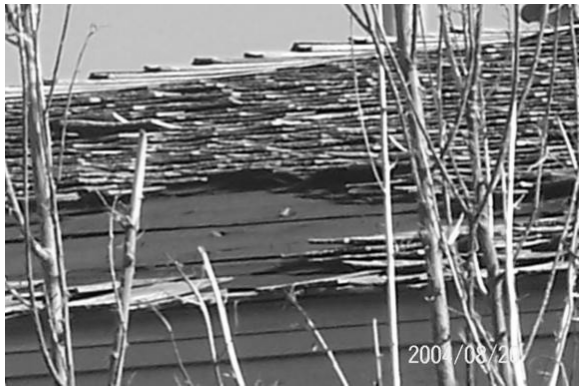
R905.2.7.2 Underlayment and high wind. Underlayment applied in areas subject to high winds [greater than 110 mph (177km/h) per Figure R301.2(4)] shall be applied with corrosion-resistant fasteners in accordance with manufacturer's installation instructions. Fasteners are to be applied along the overlap not farther apart than 36 inches (914 mm) on center.

R905.2.8.1 Base and counter flashing. Base and counter flashing shall be installed in accordance with manufacturer's installation instructions, or a continuous metal "L" flashing shall be set in approved flashing cement and set flush to base of wall and over the underlayment. Both horizontal and vertical metal flanges shall be fastened 6 inches (152 mm) on center with approved fasteners. All laps shall be a minimum of 4 inches (102 mm) fully sealed in approved flashing cement. Flashing shall start at the lower portion of roof to ensure water-shedding capabilities of all metal laps. The entire edge of the horizontal flange shall be sealed covering all nail penetrations with approved flashing cement and membrane. Shingles shall overlap the horizontal flange and shall be set in approved flashing cement.

Base flashing shall be of either corrosion-resistant metal provided in Section R905.2.8.1 or mineral surface roll roofing weighing a minimum of 77 pounds per 100 square feet (3.76 kg/m2). Counter flashing shall be corrosion-resistant metal with a minimum thickness provided in Table 903.1.

R905.2.8.6 Drip edge. Drip edge shall be provided at eaves and gables of shingle roofs, and overlapped a minimum of 2 inches (51 mm). Eave drip edges shall extend ¼ inch (6.4 mm) below sheathing and extend back on the roof a minimum of 2 inches (51 mm). Drip edge shall be mechanically fastened a maximum of 12 inches (305 mm) on center. Drip edge at eaves shall be permitted to be installed either over or under the underlayment. If installed over the underlayment, there shall be a minimum 2 inch (51 mm) width of roof cement installed over the drip edge flange.

Wood



Shake either pulled nails loose, tore from nails, or caused rusted nails to break.

Image courtesy of: RICOWI – Joe Wilson

105

Captiva

Unscathed 15-year-old wood roof in Boca Grande

Image courtesy of: RICOWI – Joe Wilson

106

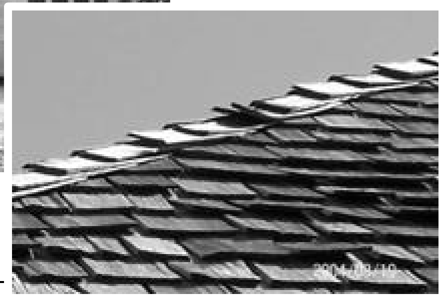
7- to 8-year-old wood shake roof.
Over-exposure (14 in.) on hip loss.

Images courtesy of: RICOWI – Joe Wilson

107

- Heavy shake
- Large overlap

Some wood hip/ridge pieces lost



Images courtesy of: RICOWI – Joe Wilson

108

Nailed wood shakes with little field loss, but stapled hips fared worse.

Images courtesy of: RICOWI – Joe Wilson

Wood shake loss from nailing 20 in. from butt

Images courtesy of: RICOWI – Joe Wilson

110

- Standard or thin shake
- Large exposed lap
- Amount of overlap of shingles stiffens roof—5 inch lap exposure stronger than 8 inch exposure
- Also, different thickness of shakes

See R905.7 of the *2004 Florida Building Code, Residential* to view sections related to wood shingles and Section R905.8 for information related to wood shakes.

Observed (and/or possible) modes of failure—steep-slope

- Age and maintenance
- Force of winds exceeded design
- Improper selection of materials
- Insufficient attachments
- Structural failure
- Workmanship

111

Mechanisms of failure: age

Image courtesy of: RICOWI – Joe Wilson

112

Not enough examples statistically, but older roofs did not seem to do as well.

Mechanisms of failure: winds exceeding roof/structure design

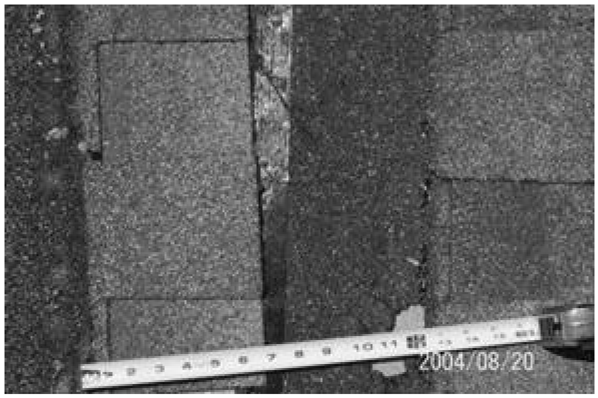
Roof basically intact, but substrate lost at eave and ridge.

Image courtesy of: RICOWI – Joe Wilson

113

Maybe the building wasn't designed for the wind conditions.

Mechanisms of failure: improper materials selection



Asphalt shingle "seconds"

Image courtesy of: RICOWI – Joe Wilson

114

Mechanisms of failure: insufficient attachments

Image courtesy of: RICOWI – Joe Wilson

115

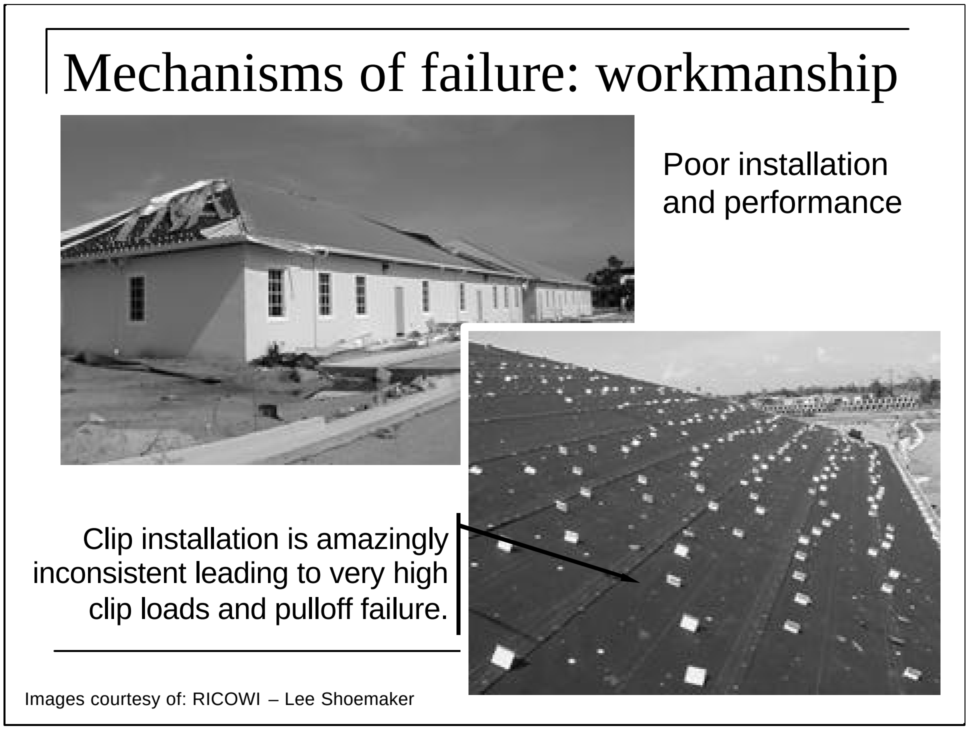
Mechanisms of failure: structural failure

Internal Pressurization

Image courtesy of: RICOWI – Joe Wilson

116

The wind came in through the broken window and out through the roof.



Port Charlotte office building:

- Clips should be in straight rows
- There was no indication of any clips in open areas

Low-slope roofing

- Investigations were primarily of commercial businesses, schools, and hospitals
- Built-up roofs are covered in FBC, Residential Section R905.9

118

See R905.9 of the *2004 Florida Building Code, Residential* to view sections related to built-up roofs.

Note that Table R905.9.2, related to material standards, is expanded in the new code.

Also, Section R905.9.2.1 states:

> Red rosin paper shall be used when the membrane is applied directly to a wood deck or cementitious fiber decks.

Independent testing organizations

- Underwriters Laboratories (UL) and FM Global test various roofing systems for wind uplift performance and then publish the results in their directories.

119

Useful websites

Organization	Website
Florida Roofing, Sheet Metal and Air Conditioning Contractors Association	www.floridaroof.com
National Roofing Contractors Association	www.nrca.net
Building A Safer Florida, Inc.	www.buildingasaferflorida.com
Institute for Business and Home Safety	www.ibhs.org
Federal Alliance for Safe Homes	www.flash.org
Florida Building Code Information	www.floridabuilding.org

120

More useful websites

Organization	Website
Building Officials Association of Florida	www.boaf.net
Miami-Dade product approval	http://www.miamidade.gov/buildingcode/pc_home.asp
Florida's product approval system	www.floridabuilding.org
Insurance discounts at the Mitigation Database site	www.floridawindincentives.org
Department of Financial Services Office of Insurance Regulation	www.fldfs.com /deductible

- See http://www.ricowi.com to determine availability of RICOWI WIP final report, which aims to be a factual resource of the performance of roof systems in high winds, including a summary report of Hurricanes Charley and Ivan best-verifiable wind speeds.

- By the way...
  RICOWI and DOE/ORNL will, if needed, respond to another hurricane in 2005.

123

Course Evaluation

Course Title: Residential Roofing and Hurricanes

Date: ____________________ **Location:** ______________________

Please circle your response:	**Strongly Disagree**	⟷			**Strongly Agree**
Question 1: The course objectives were accomplished.	1	2	3	4	5
Question 2: The course started and finished on time.	1	2	3	4	5
Question 3: The instructor(s) was well-versed in their topic and well-prepared.	1	2	3	4	5
Question 4: The materials presented were effective.	1	2	3	4	5

What did you like most about the course?

What did you like least about the course?

Please list other comments about this course, including ways to improve the course or suggestions for other courses.