RICOWI, Inc.

Roofing Industry Committee on Weather Issues, Inc.

Hurricanes Charley and Ivan Wind Investigation Report

March 2006

In cooperation with the

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

UT-BATTELLE

HURRICANES CHARLEY AND IVAN INVESTIGATION REPORT

March 2006

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PREFACE

This document was prepared and published by the Roofing Industry Committee on Weather Issues, Inc. (RICOWI).

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ABBREVIATIONS, ACRONYMS, AND INITIALISMS

ANSI	American National Standards Institute
ARA	Applied Research Associates
ARMA	Asphalt Roofing Manufacturers Association
ASCE	American Society of Civil Engineers
BUR	built-up roofing/built-up roof
CMU	concrete masonry unit
CRADA	cooperative research and development agreement
CSSB	Cedar Shake and Shingle Bureau
CWF	cementitious wood fiber
DOE	U.S. Department of Energy
EIFS	exterior insulation finished system
EP	ethylene propylene
EPDM	ethylene propylene diene monomer
EPS	expanded polystyrene
ERA	EPDM Roofing Association
FEMA	Federal Emergency Management Agency
FM	Factory Mutual
HVAC	heating, ventilating, and air-conditioning
IBHS	Institute for Business and Home Safety
ISANTA	International Staple, Nail and Tool Association
LPS	lightning protection system
LWIC	lightweight insulating concrete
MB	modified bitumen
MBMA	Metal Building Manufacturers Association
MCA	Metal Construction Association
NOAA	National Oceanic and Atmospheric Administration
NRCC	National Research Council of Canada
o.c.	on-center
ORNL	Oak Ridge National Laboratory
OSB	oriented strand board
PVC	polyvinyl chloride
RCI	Roof Consultants Institute

RICOWI	Roofing Industry Committee on Weather Issues, Inc.
SPF	spray polyurethane foam
SPFA	Spray Polyurethane Foam Alliance
SPRI	Single Ply Roofing Industry
TPO	thermoplastic polyolefin
TRI	Tile Roofing Institute
WIP	Wind Investigation Program

ABSTRACT

Roofing Industry Committee on Weather Issues, Inc. (RICOWI) teams were deployed to investigate damage caused by Hurricanes Charley, Ivan, and Katrina. This report covers the investigations for Hurricanes Charley (August 13, 2004) and Ivan (September 16, 2004). Hurricane Katrina data are slated to be covered in a future report.

Nearly every type of building and roof system was encountered in these investigations. Results from these studies are included in the damage reports. Best estimated wind speed data are included, as are criteria for site selection and general observations. The report contains the investigation protocol, meteorological data from the storms, and team information.

EXECUTIVE SUMMARY

The investigation report of Hurricanes Charley and Ivan is the fruition of 10 years of planning for a major wind event that met the criteria of the Roofing Industry Committee on Weather Issues, Inc. (RICOWI) membership. The Wind Investigation Program (WIP) was initiated in 1996 with these major objectives:

- To investigate the field performance of roofing assemblies after major wind events
- To factually describe roofing assembly performance and modes of failure
- To formally report the results of the investigations and damage modes for substantiated wind speeds

The goal of the WIP was to perform unbiased, detailed investigations by credible personnel from the roofing industry, the insurance industry, and academia. Data from these investigations will, it is hoped, lead to overall improvement in roofing system durability and a reduction in insured losses, which may lead to lower overall costs to the public. Two major hurricane events in 2004 finally provided the opportunity for execution of the WIP plan. This report documents the achievement of the objectives through execution of an extensive and well-planned investigative effort. Estimated wind speeds at the damage locations came from simulation of the hurricane wind fields along the paths by the Hurricane Research Center and others.

Hurricane Charley made landfall near the Punta Gorda–Port Charlotte area of Florida as a Category 4 hurricane on Friday, August 13, 2004. Charley was the first storm to meet the RICOWI WIP criteria of "greater than 95 mph sustained wind speeds over a populated area." Seven teams involving a total of 39 persons fanned out over the area to document damage to both low slope and steep slope roofing systems. The teams collected specific information on each building examined, including roof shape, roofing system materials, edge conditions, installation details, and degree of deterioration, if any. With each team member assigned a specific duty, they described the damage in detail and illustrated important features with numerous colored photographs. Where possible, the points of damage initiation were identified, along with possible reasons for the initial failure. Owing to their extensive experience and knowledge of roofing technology, succinct observations and assessments were made as team members identified causes of failure and the consequences.

Hurricane Ivan made landfall on September 16, 2004, west of Pensacola, Florida, as a Category 2 hurricane. Five teams (21 persons) conducted an extensive wind damage investigation, again looking at low slope and steep slope roofing systems. The personnel gained valuable experience in the Charley investigation, which is reflected in the Ivan report. The same general format is used in the Ivan report.

LOW SLOPE

Wind-related damage conditions observed on the 93 roofs ranged from minor to extensive. Damage conditions included loss of edge metal; punctures/tears in roof membranes; withdrawal and pull-over of securement fasteners; and, at some locations, complete displacement (blow-off) of the roof system.

The roofs exhibited some commonality in where wind damage began, how damage progressed, and causes of damage. Events believed associated with initiation of wind damage included the following:

- Lifting of edge metal (cleat deformation or absence, and flashing disengagement)
- Billowing of membranes and membrane base flashings (air infiltration into spaces behind base flashings and below roof membranes)

- Puncturing/tearing of the roof membrane from wind-borne debris and wind-toppled equipment
- Release of deck panels from attachment points

Scenarios of how wind damage progressed from initiation points included the following:

- Membrane billowing, fastener pull-out (at termination bars and sheathing boards), displacement of sheathing boards and/or base flashings, and membrane tearing and/or peeling at fasteners
- Edge cleat deformation, edge metal deflection, edge metal and/or nailer lifting, and roof membrane tearing (around fasteners) and peeling
- Debris puncturing membrane, wind billowing membrane near puncture, and membrane tearing (mechanically attached single-ply roofs only)

Conditions most often associated with damage observations included these:

- Deteriorated roof attachment systems (resulting in a reduced wind uplift resistance)
  - Corroded fasteners
  - Deteriorated wood substrates
  - Deteriorated mechanically attached base sheets
- Roof constructions that varied from common industry recommendations
  - No increase of mechanical attachment in perimeters or corners to compensate for increased loads as specified in ASCE 7 and FM-1-29
  - Edge metal cleat gauges and wood nailer securement less than recommended in FM Global LPDS 1-49 (1979) and ANSI/SPRI ES-1 (adopted in 2003 IBC)
- Roof constructions that included openings that allowed rapid air infiltration between roof membranes and roof decks
- Locations exposed to wind-borne debris

STEEP SLOPE

Wind-related damage conditions observed on 91 steep slope roofs ranged from minor to extensive. Damage conditions included insufficient attachment, component detachment, and complete displacement (blow-off) of the roof system. Workmanship and improper material selection issues were major factors in the observed damage.

The roofs exhibited similarities in where wind damage began and how the damage progressed. Events believed associated with initiation of wind damage included the following:

- Insufficient attachment: Insufficient fastener attachment was commonly observed in both the types and the number of fasteners used.
- Insufficient fasteners: Cases were observed where the fastener was not sufficient, in conjunction with the frequency of placement, to resist the wind forces.
- Inappropriate fastener placement: Examples of roof failure occurred where fasteners and placement patterns were used that would not normally have been specified or prescribed for a particular application.
- Building code changes: It was found that the fastening requirements specified in a later version of the building code were an improvement over those of the earlier code. Insufficient attachment was also prevalent in the securing of substrates and framing members.
- Workmanship. The teams observed instances where the construction of the roof covering compromised its performance against the hurricane-force winds. Cases were found of missing or improperly placed fasteners. Other cases were found where the construction of the building's roof covering was not according to the governing code or standard practice at the time of construction.

- Improper material selection. Examples were found of roofs where either one component or a combination of components failed to withstand the force of winds. The failure of one component used on the roof or as part of the roof structure was found to influence the performance of other materials. Roofs that were exposed to and survived the hurricane winds were supported by an entire system having the required materials installed according to specification.
- Structural failure. Cases were observed in which the structural integrity of the building was breached and the roof failed.
- Age and maintenance. In some cases in which similar material types were used, newer roofs performed better in the hurricanes than did older materials. Some of the performance differences between older and newer materials can be attributed to better-specified application methods; but in similar roofs with equivalent application methods, it was observed that newer roofs fared better than older ones. Examples were found in which the performance of the roof was weakened by corrosion or deterioration of components.
- Winds in excess of code design. In some instances, the roof system failed even though it was constructed according to an appropriate updated specification. These examples were found for both the roof covering and the building's structure.

The data and the subsequent assessments will hopefully be used by product manufacturers, roofing system designers, roofing contractors, and building officials to improve the performance of roofing systems in high winds. The efforts expended by the team members, the financial support from all the contributors, and the help of the sponsoring organizations will no doubt be of great benefit to the roofing industry in the future.

RESULTS

The investigation of Hurricanes Ivan and Charley provided valuable information on the performance of roofing exposed to hurricane-force winds. The investigation teams were able to discern the effectiveness of materials and methods of construction in resisting these winds. A variety of damage modes were observed in the hurricane-struck areas, including roof attachment, material selection, roof/structure design, deterioration, and workmanship. Many of the performance characteristics observed in Hurricane Charley were again observed in Ivan. During the investigations of Ivan and Charley, our teams found that generally roofing installed according to the latest codes resisted damage from the winds. The information gathered on some types of materials provides an understanding of the materials' performance characteristics when installed in accordance with the customary method for that area. The participating associations will develop specific recommendations for new installation procedures and building code changes based on the data and reports.

The investigations were also a learning laboratory for the investigation procedures used. It was clearly shown that investigations need to be under way soon after landfall to capture the progression of damage. Repairs of essential facilities are usually under way as soon as the debris can be adequately cleared and access is available. A preliminary assessment team with flyover and aerial photo capabilities provides the information that allows the best use of resources in the investigations. This is most important in locating low slope rooftops that cannot be observed from the ground. Logistics is critical to successful investigations. Housing near the inspection area, although difficult to obtain, led to effective use of the manpower resources provided in these investigations.

Installation of roofs systems as a minimum should meet the minimum code requirements in hurricane zones and follow best industry practices and manufacturers' guidelines. Owners and specifiers are urged to consider designing systems that exceed current code requirements. Systems should follow the performance requirements, including appropriate testing, specified by the applicable building code.

All building envelope components are affected by weather-related aging; therefore, sufficient maintenance of buildings is important. The studies reinforced the need for secure roof edges, and codes that require secure roof edging need to be enforced. Wind-borne debris was also a major contributor to roof damage, and standards and enforcement are needed for attachment of all building envelope components to help reduce wind-borne debris (e.g., air handling units).

FUTURE RESEARCH

Future hurricane wind investigations would prove valuable in collecting additional information on the performance of roofing exposed to hurricane force-winds. Some questions or suppositions were resolved from information gathered during the Charley and Ivan events; but, at the same time, other questions surfaced. For example, it was observed that some roofing materials were more prone to damage when located on gable-constructed homes or around wall protrusions or dormers. More investigations are necessary to verify these and other observed phenomena. Although an effort was made to investigate all types of roofing, some types were not found in the areas affected by Charley and Ivan. Therefore, further investigation is warranted in areas that contain other types of roofing or construction methods not previously observed.

In particular, it would be valuable to conduct an additional survey in the same areas previously investigated by our teams, or in a location that had recently been rebuilt after a hurricane. Also of interest would be investigations in areas that have installed substantial amounts of roofing in accordance with the latest code revisions. Questions regarding the adequacy of the building code arise after an area is ravaged by a hurricane, and investigations are warranted when serious questions are raised by governing authorities. Investigations can distinguish whether the damage is caused by non-conformance to code standards or if the code is adequate. The goal of RICOWI investigations is to gather the facts, and facts are necessary when there is a general push for change that is perhaps fueled by supposition or concerns raised by false information. The unique, balanced composition of RICOWI teams (members from industry, science/research, and consultation) results in the documentation of facts without bias.

RICOWI investigations are conducted with a forensic scope and are not intended for statistical analysis, but the investigation criteria in future events might be amended to allow for larger samplings. Other search criteria could be added, as appropriate, to gather information not previously considered. The criteria for event mobilization could be modified according to the information that might be desired from a particular area impacted by a hurricane. In other words, in the future, the decision regarding whether to activate for an investigation can be based more on the potential value of the information to be gathered, rather than the prior criteria based on a hurricane with 95-mph (one minute sustained) winds striking any major populated area in the continental United States.

INTRODUCTION

INVESTIGATION PROTOCOL

The scope of work under the cooperative research and development agreement (CRADA) established between Oak Ridge National Laboratory/U.S. Department of Energy (ORNL/DOE) and the Roofing Industry Committee on Weather Issues, Inc. (RICOWI) is to investigate and report the field performance of low slope and steep slope roofing systems after a major hurricane, with a sustained wind speed of 95 mph (1 minute sustained) or greater, makes landfall on the continental United States in a populated area. Both Hurricanes Charley and Ivan met those basic criteria.

ORNL hosted an initial training seminar for investigation team members in 1996. Subsequent training workshops were held in September 2000 and March 2005. DOE supplied identification badges to each trainee attending the workshop at its facility in Oak Ridge, Tennessee. DOE badges were instrumental in gaining access to disaster areas.

Generally, team members are wind engineers, roofing material specialists, insurance analysts, structural engineers, and/or roofing consultants. During the Charley investigation, five Federal Emergency Management Agency representatives became team members. Some teams were accompanied by roofing contractors or other interested parties who aided in arranging inspections or in providing access and equipment.

Inspector training, which focused on wind dynamics, damage modes, and documentation, was attended by all ORNL–badged participants. Training was conducted by a number of the country's leading wind engineers, scientists, roof consultants, and others qualified in examining wind-related roof damage.

Each team had four positions: (1) report writer, (2) photographer, (3) data recorder, and (4) sample collector. All team members acted as observers, combining their expertise and observations to maximize the data obtained from each investigation. Members were assigned to specific teams based on their respective fields of expertise. Each team was balanced by assigning two manufacturing members and two members from academia, the insurance industry, consulting firms, or other non-manufacturer associations.

Seven teams were deployed to Hurricane Charley damage areas, with a command center set up in Venice, Florida. Five teams were deployed for the Hurricane Ivan investigations, with a command center set up in Mobile, Alabama. Briefings were held each day to review safety protocols and site selections and to realign teams as necessary to maintain balance.

Advance clearance letters from state emergency management agencies were also obtained from all of the states located in hurricane-prone areas. Building owners, building managers, or other responsible parties were then contacted to obtain permission to inspect the roofs.

Site selection was based on collected data from local building officials, police officials, aerial photographs, news media, and industry members. Immediately after landfall, the logistics coordinator was able to conduct an early survey of each area, prepare a list of potential investigation sites, and work with the program coordinator to set up building contacts before deploying the teams.

Teams initially viewed roofs for large-scale damage and then focused on individual details and the potential causes for noted damage. Photos were taken to document conditions observed, and then recorded in photo logs. Inspection forms were used to document background information, details about the roof system and substrates, type and severity of roof damage, and any wind direction/speed information available. Following the field investigations, information from the inspection forms was added to a central database, and digital photographs from each site were similarly consolidated.

More than 115 roof inspections were conducted on all types of roofing systems, including commercial, institutional, and residential. Where possible, reports documented roof and deck construction, damage conditions, and the likely initiation points of wind damage. Adjacent buildings, foliage, signs, fences, and surrounding elements were used to establish wind direction and pathways.

Roofing material was removed and examined where possible, for example, when re-roofing or repairs were in progress. While inspections were non-destructive, samples were taken from a few locations when circumstances allowed. Structures that survived the storm or suffered minor damage were also documented.

CODE COMMENTARY

The post-hurricane evaluation of roofing performance must take into account the age of the building, and the codes enforced at the time of construction, to make reasonable comparisons to today's codes and standards. Our knowledge of wind effects and roof uplift resistance has taken great strides over the past two decades, in part because of lessons learned from previous field studies of hurricane damage.

For example, the code requirements for the wind uplift on a corner fastener in the hurricane regions is over four times higher in today's code than it was in the early 1980s. Therefore, the observation of damage to a roof on an older building is not necessarily a predictor of the performance of a building designed to current codes and standards. However, side-by-side comparisons of buildings of a different code vintage can be a good yardstick of how effective the newer code requirements are.

REPORTS

This document is divided into summary reports and reports of damage on individual buildings. They are based on observations by the team at the time of the investigation; and although the damage observed was considered to be caused by the recent hurricane, there may have been other causes.

The wind speed in this report is based on the post-hurricane maps available and refers to the wind speed at 10 meters in exposure C. The wind speeds at the site are our best estimates based on these maps. They must be adjusted for building height to obtain wind uplift pressures on the roofs. The actual wind speed at the site can vary by ±10 mph from the speed reported, and it could vary more because of downbursts, or wind streaks that are known to occur in hurricanes.

DEFINITIONS

Damage: Any wind-induced change to the pre-hurricane condition of the building. Damage conditions noted are relative to the interpretation of the observers and may not concur with insurance or other repair-related decisions.

Minor damage: Damage that was limited and unlikely to have prevented the roofing system from providing its primary function of weather protection. Minor damage generally involves only a small area of the roof.

Major damage: Damage that likely compromised the roofing system so it could no longer provide its primary function of weather protection.

Extensive damage: Damage that involved large areas of the roof covering and other building components, such as roof decks and walls.

Failure: Failure of the roof assembly (from the deck up) to remain intact, to remain properly attached to the structure, and/or to prevent infiltration of water, air, or other contaminants.

Hurricane-prone regions (ASCE7-02 excerpt): Areas vulnerable to hurricanes; in the United States and its territories, defined as

- The U.S. Atlantic Ocean and Gulf of Mexico coasts where the basic wind speed is greater than 90 mph
- Hawaii, Puerto Rico, Guam, Virgin Islands, and American Samoa

Roof covering pull-off: Roofing material pulling off the fasteners, with the fasteners remaining in the deck. Also referred to as “pull-through.”

Roof height: Distance measured from the ground to the eave.

Street survey: A survey conducted by teams walking (or slowly driving) streets to determine primary damage and extent of damage to steep roofs. In some instances, teams were able to discern types of roofs and, to some extent, age of installation.

Surface roughness: (ASCE7-02 excerpt): A ground surface roughness within each 45° sector shall be determined for a distance upwind of the site, as defined in the exposure categories below, for the purpose of assigning an exposure category, as defined in exposure categories.

- **Surface roughness B:** Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.
- **Surface roughness C:** Open terrain with scattered obstructions having heights generally less than 30 ft (9.1 m). This category includes flat, open country; grasslands; and all water surfaces in hurricane-prone regions.
- **Surface roughness D:** Flat, unobstructed areas and water surfaces outside hurricane-prone regions. This category includes smooth mud flats, salt flats, and unbroken ice.

Wind exposure categories (ASCE7-02 excerpt):

- **Exposure B:** Exposure B shall apply where the ground surface roughness condition, as defined by surface roughness B, prevails in the upwind direction for a distance of at least 2630 ft (800 m) or 10 times the height of the building, whichever is greater.
  - Exception: For buildings whose mean roof height is less than or equal to 30 ft (9.1 m), the upwind distance may be reduced to 1500 ft (457 m).
- **Exposure C:** Exposure C shall apply for all cases where exposures B or D do not apply.
- **Exposure D:** Exposure D shall apply where the ground surface roughness, as defined by surface roughness D, prevails in the upwind direction for a distance at least 5000 ft (1524 m) or 10 times the building height, whichever is greater. Exposure D shall extend inland from the shoreline for a distance of 660 ft (200 m) or 10 times the height of the building, whichever is greater.

For a site located in the transition zone between exposure categories, the category resulting in the largest wind forces shall be used. Exception: An intermediate exposure between the above categories is permitted in a transition zone provided that it is determined by a rational analysis method defined in the recognized literature.

Wind speed. The 3-second gust wind speeds at 10 meters (33 feet) in wind exposure C as defined by ASCE 7.

HURRICANE CHARLEY INVESTIGATION

METEOROLOGICAL INFORMATION

On Friday, August 13, 2004, Hurricane Charley made landfall at Port Charlotte and the community of Punta Gorda as a Category 4 hurricane. This made Hurricane Charley the strongest wind event in the United States since Hurricane Andrew in 1992. With wind speeds estimated at over 150 mph for sustained winds and well over 170 mph for gusts, Charley provided the first opportunity for observation of a “code event” in 23 years.

Although Charley’s radius was more than 200 miles, the eye of the storm that provided the peak winds was only about 15 miles in diameter. Hurricane Charley traveled in a northeasterly direction at about 15–20 mph, bringing extensive rainfall from Port Charlotte to Orlando in the outer bands of the storm. At the Orlando airport, wind speeds in excess of 105 mph were recorded as the storm passed through. The wind speeds used in this report are from the National Oceanic and Atmospheric Administration (NOAA), Applied Research Associates (ARA), the Federal Emergency Management Agency (FEMA), and other sources. Definitive “official” wind speeds are not available at the time of this writing. Although the severe damage area was relatively narrow, there was an opportunity for observation in the outer areas of the storm’s path where wind speeds may have been below design level.

See Appendices A–C for wind maps used in this study.

FIELD INVESTIGATIONS

The Hurricane Charley field investigations in the following sections are divided into low slope and steep slope systems. They are presented in the following order:

Low Slope Systems
- Team 2
- Team 3
- Team 5
- Team 6

Steep Slope Systems
- Team 1
- Team 4
- Team 7

HURRICANE CHARLEY

LOW SLOPE ROOF SYSTEMS

HURRICANE CHARLEY: TEAM 2

OVERVIEW

Members of Team 2 were assigned to gather data on sprayed polyurethane foam (SPF) roof systems. The team had little information as to specific locations of buildings with SPF roofing, so it toured heavily damaged areas in Punta Gorda and Port Charlotte, Florida, to find suitable sites.

Team Members

Robb Smith, Captain and Report Writer
Tom Kelly, Photographer
Dave Roodvoets, Data Collector (August 18 and 19)
Roger Morrison, Sample Collector (August 18, 20, and 21)
Maria Luisa Rouco, Sample Collector (August 19, 20, and 21)

Scope

On August 18 and 19, 2004, the team toured the initial areas of the city of Punta Gorda and Port Charlotte. Locating SPF roofs was difficult, given the typically low percentage of SPF used on low slope roofs. Nevertheless, seven SPF roofs were located through contacts with manufacturers and contractors, and a little luck. The following report is a summary of the field data that were obtained.

General Building Information

Address	City	Roof height	Type of structure	Roof size (ft.^{2})	ASCE exposure category	Deck type	Roof assembly	Extent of damage
1601 W. Marion	PG	24	Office	7,680	B	Steel	MB/SPF	Extensive
1625 W. Marion	PG	14	Office	36,000	B	Plywood	BUR/SPF	Minor
1780 W. Marion	PG	16	Yacht club	14,000	B	Wood plank	BUR/SPF	Extensive
5054 Hwy 41 N.	PC	12	Restaurant	3,984	B	Plywood	BUR/SPF	Minor
21260 Olean Blvd.	PC	28	Bank	13,100	B	Steel	LWIC/BUR/ SPF	Moderate
22375 Edgewater	PC	20	Condos	8,288	B	Plywood	BUR/SPF	Minor
21062 Edgewater	PC	12	SF Residence	1,786	B	Plywood	Concrete Tile/SPF	Minor
Total	**7**			**84,838**				

Building Construction

Most surveyed roofs had wood decks originally covered with built-up roofing (BUR). Two other roofs had steel substrates; one was steel pan with integral lightweight insulating concrete (LWIC), and the other was steel decking with polyisocyanurate board insulation. Edge flashing was typically metal. Exceptions were a bank building, which had a parapet surrounding most of the perimeter, and a residence with no edge flashing at the eave of the steep slope roof. All roofs were two stories or less and were less than 28 ft. above the ground.

Damage Observed

The mode of initial damage was typically related to perimeter edge flashing. The degree of roof attachment damage was increased when the building was pressurized as a result of broken windows. Investigation of edge flashing showed that spacing of fasteners on the metal edge metal flange was typically 10 to 16 in. o.c., rather than the industry standard of 3 to 6 in. o.c. At the yacht club, it was determined that new “foam stop” edge flashing was not installed with the newer SPF roof, as recommended by the SPF industry; instead, the installer re-used the older BUR edge flashing. The flange of the BUR edge flashing was fastened 8 to 10 in. o.c., versus the industry standard of 3 to 6 in. o.c.

Because it is common for SPF to be applied over existing roofing, SPF applicators typically assume that the existing roof system is properly fastened to the structure. None of the damaged SPF roofs observed displayed the industry fastening standard for base sheets of 9 in. o.c. at side laps, with an additional two interior rows 12 in. in from each edge fastened at 18 in. o.c. Observed side lap fastening was 13 to 18 in. o.c., with the two interior rows fastened at 20 to 24 in. o.c.

Virtually all of the SPF roofs contained some degree of gouges, cuts, and crushed foam, apparently caused by impact of wind-borne debris.

Conclusions

Although SPF surfaces remain susceptible to impact damage, such damage tends to be easily repaired, often with a few tubes of urethane sealant. Most observed SPF roofs would likely have continued to perform well if (1) an actual foam stop had been installed at the perimeter, (2) the old BUR had received additional fastening prior to SPF application, and (3) mechanical equipment had been properly anchored to the structure.

INDIVIDUAL ROOF REPORTS

2.01 1601 W. Marion, Punta Gorda

TYPE OF STRUCTURE—Office

EXPOSURE—B

WALL CONSTRUCTION—Steel

ROOF TYPE—SPF over single ply of modified bitumen (MB), which was torch-applied over polyisocyanurate insulation

ROOF HEIGHT—24 ft.

ROOF AREA—7,680 $ft.^2$

ROOF SLOPE—¼":12"

ROOF DECK—Steel

WIND SPEED—140–150 mph

View of the NW corner of 1601 W. Marion.

NOTED DAMAGE—Building sustained 100% roof damage, with 100% of the roof membrane blown off or delaminated. Several large windows were blown out first, pressurizing the building. Negative and positive pressures exceeded the roof’s structural integrity. Improper insulation fastening methods and insulation facer delamination were also noted.

COMMENTS—The dates of initial construction and subsequent re-roofing were not determined. The building is adjacent to inland water areas of Punta Gorda and may have experienced storm winds from both the east and west as the storm traveled through.

(For more photos of buildings, see end of this section.)

2.02 1625 W. Marion, Punta Gorda

TYPE OF STRUCTURE—Office

EXPOSURE—B

WALL CONSTRUCTION—Wood

ROOF TYPE—SPF over BUR

ROOF HEIGHT—14 ft.

ROOF AREA—36,000 ft.^{2}

ROOF SLOPE—¼":12"

ROOF DECK—Plywood

WIND SPEED—140–150 mph

View of the NE corner of 1625 W. Marion.

NOTED DAMAGE—Building sustained less than 10% roof damage, mostly from missile impact to the SPF, lack of equipment anchoring, and loss of the perimeter steel/wood-framed mansard/screen. No edge damage was observed.

PRELIMINARY DAMAGE INITIATION AND PROPAGATION ASSESSMENT—Easterly winds destroyed most of the mansard/screen.

COMMENTS—The dates of initial construction and subsequent re-roofing were not determined. The building is adjacent to the inland water areas of Punta Gorda and may have experienced storm winds from both the east and west as the storm traveled through.

2.03 1780 Marion, Punta Gorda

TYPE OF STRUCTURE—Yacht Club

EXPOSURE—B

WALL CONSTRUCTION—Wood

ROOF TYPE—SPF over BUR

ROOF HEIGHT—10–16 ft.

ROOF AREA—14,000 ft.^{2}

ROOF SLOPE—¼":12"

ROOF DECK—Wood plank

WIND SPEED—140–150 mph

View of 1780 Marion.

NOTED DAMAGE—Building sustained less than 15% roof damage, mostly from wind-borne debris impact on the SPF, lack of equipment anchoring, loss of perimeter metal edge flashing, BUR/SPF membrane blow-off, and minor fascia damage.

PRELIMINARY DAMAGE INITIATION AND PROPRAGATION ASSESSMENT—Easterly winds appear to have peeled back portions of the edge flashing at the most easterly point on this round building.

COMMENTS—The dates of initial construction and subsequent re-roofing were not determined. The building is adjacent to the inland water areas of Punta Gorda and may have experienced storm winds from both the east and west as the storm traveled through.

2.04 5054 N. Hwy 41, Port Charlotte

TYPE OF STRUCTURE—Restaurant

EXPOSURE—B

WALL CONSTRUCTION—Wood

ROOF TYPE—SPF over BUR

ROOF HEIGHT—10 ft.

ROOF AREA—3,984 $ft.^2$

ROOF SLOPE—¼":12"

ROOF DECK—Plywood

WIND SPEED—130–140 mph

View of the west side of 5054 N. Hwy. 41.

NOTED DAMAGE—The building sustained less than 5% roof damage, mostly resulting from inadequate edge flashing installation.

PRELIMINARY DAMAGE INITIATION AND PROPAGATION ASSESSMENT—Easterly winds blew off most of the unprimed galvanized metal edge flashing because the flange was fastened at varying distances up to 16 in. o.c.

COMMENTS—The dates of initial construction and subsequent re-roofing were not determined. The building is adjacent to the inland water areas of Punta Gorda and may have experienced storm winds from both the east and west as the storm traveled through.

2.05 21260 Olean Blvd, Port Charlotte

TYPE OF STRUCTURE—Bank

EXPOSURE—B

WALL CONSTRUCTION—Steel

ROOF TYPE—SPF over LWIC

ROOF HEIGHT—18 ft.

ROOF AREA—13,100 $ft.^2$

ROOF SLOPE—¼":12"

ROOF DECK—Steel/LWIC

WIND SPEED—130–140 mph

View of the SE corner of 21260 Olean Blvd.

NOTED DAMAGE—Building sustained less than 10% roof damage, mostly resulting from damage to edge flashing.

PRELIMINARY DAMAGE INITIATION AND PROPAGATION ASSESSMENT—Roof damage occurred where there was no parapet on the north elevation.

COMMENTS—The dates of initial construction and subsequent re-roofing were not determined.

2.06 22375 Edgewater, Port Charlotte

TYPE OF STRUCTURE—Condominium

EXPOSURE—B

WALL CONSTRUCTION—Concrete

ROOF TYPE—SPF over BUR

ROOF HEIGHT—20 ft.

ROOF AREA—8,288 $ft.^2$

ROOF SLOPE—¼":12"

ROOF DECK—Plywood

WIND SPEED—130–140 mph

View to the east at 22375 Edgewater.

NOTED DAMAGE—Building sustained less than 10% roof damage, all limited to foam stop edge flashing.

PRELIMINARY DAMAGE INITIATION AND PROPAGATION ASSESSMENT—Easterly winds blew off most of the galvanized metal foam stop edge flashing fastened at 16 in. o.c.

COMMENTS—Building is one of 18 in this condominium development. Other visible buildings experienced similar damage. The dates of initial construction and subsequent re-roofing were not determined. Building is located approximately one mile north of the Peace River and may have experienced storm winds from both the east and west as the storm traveled through. Roof was blown onto an adjacent property.

2.07 21062 Edgewater, Port Charlotte

TYPE OF STRUCTURE—Single family residence

EXPOSURE—B

WALL CONSTRUCTION—Wood

ROOF TYPE—SPF over concrete tile

ROOF HEIGHT—12 ft.

ROOF AREA—1,786 $ft.^2$

ROOF SLOPE—3":12"

ROOF DECK—Plywood

WIND SPEED—130–140 mph

View of the north slope of 21062 Edgewater.

NOTED DAMAGE—Building sustained less than 1% roof damage, mostly at the eave.

PRELIMINARY DAMAGE INITIATION AND PROPAGATION ASSESSMENT—Damage from wind-borne debris, including fragments of a near-by tile roof.

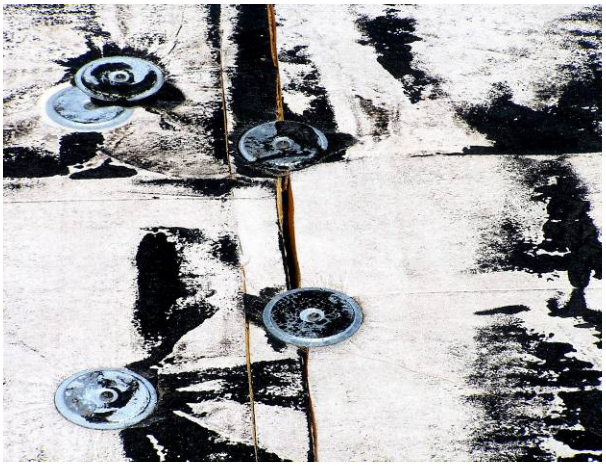
COMMENTS—The dates of initial construction and subsequent re-roofing were not determined. This building is located on an inland waterway approximately two miles north of the Peace River. It may have experienced storm winds from both the east and west as the storm traveled through.

PHOTOGRAPHS OF ROOF DAMAGE

1601 W. Marion, Punta Gorda

2-01-1. Extensive roof loss on east half of building.

2-01-2. A modified bitumen membrane was bonded to insulation facer. The facer peeled away from the polyisocyanurate insulation boards.



2-01-3. The typical random insulation fastening pattern used here was not in compliance with manufacturer recommendations. Note that fastener disks span two pieces of insulation, which is inconsistent with industry standards and good workmanship.

2-01-4. More poor insulation fastening is visible here.

1625 W. Marion, Punta Gorda

2-02-1. This area had very little damage to SPF roofing.

2-02-2. This is a typical example of damage from wind-borne debris.

2-02-3. This mechanical equipment was not properly fastened. Also, there was improper detailing of SPF at equipment stand.

2-02-4. Synthetic tile (not clay or concrete) was blown off this screen/fence. SPF edge flashing was intact and undamaged.

1780 Marion, Punta Gorda

2-03-1. Edge flashing damage at the east side initiated roof blow-off. Inadequate anchoring of mechanical equipment also damaged the SPF roof.

2-03-2. Old built-up roof edge flashing was used in lieu of installing new foam stop edge flashing. Nails pulled loose from decayed wood at fascia.

2-03-3. Fastening of original BUR sidelaps at 13 to 14 in. o.c., rather than 9 in. o.c., contributed to the blow-off.

2-03-4. This roof appears to have been in the path of winds from both the east and the west.

5054 N. Hwy 41, Port Charlotte

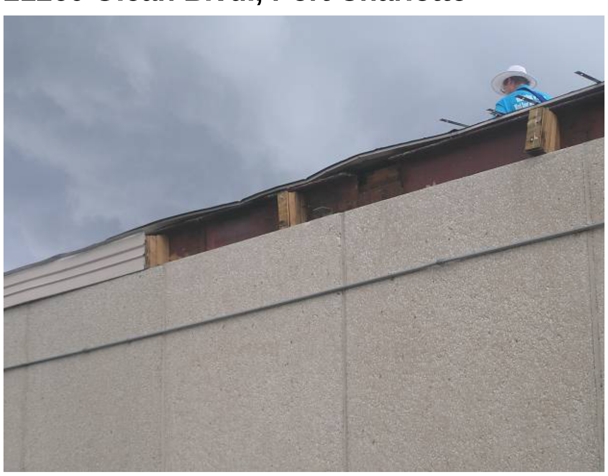
2-04-1. Most of the mechanical equipment remained on the roof.

2-04-2. Damage was limited to edge flashing with no damage to field of roof.

2-04-3. This metal edge flange was not primed prior to SPF application.

2-04-4. Inadequate nailing of this metal edge resulted in flashing damage.

21260 Olean Blvd., Port Charlotte



2-05-1. Edge flashing damage.

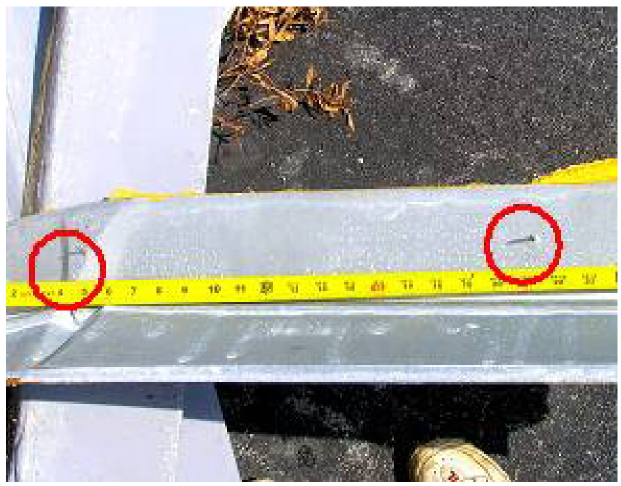
2-05-2. This roofing substrate consisted of LWIC over EPS insulation, over a steel deck.

22375 Edgewater, Port Charlotte

2-06-1. Built-up roofing blew off a separate building below this SPF roof, but the SPF roof suffered only edge damage.

2-06-2. SPF edge repair was in progress during our visit (note yellow foam).

2-06-3. Asphalt strip shingle-clad mansard suffered minor damage on some windward exposures.



2-06-4. This foam stop edge flashing was fastened at 16 in. o.c. instead of the industry standard of 3 to 6 in. o.c.

21062 Edgewater, Port Charlotte

2-07-1. Some pieces of tile were broken off at the windward eave.

2-07-2. Minor wind-borne debris damage occurred at a few points on the roof.

2-07-3. Note the extensive asphalt 3-tab strip shingle loss on the neighbor's roof (near top of photo).

HURRICANE CHARLEY: TEAM 3

OVERVIEW

Charley Team 3 focused primarily on low slope roof coverings on county facilities and commercial buildings in Punta Gorda and Arcadia, Florida. Team 3 observed nine roofs at seven different sites, documenting roof construction, wind damage, and probable initiation points of wind damage. Figure 1 shows approximate locations of sites 1 through 7. Figure 2 shows approximate locations of sites 8 and 9. Of the nine roofs, eight were on low-rise buildings (less than 60 ft. high) in either exposure B or C. All nine had single-ply roof coverings, including mechanically attached (both loose-laid and ballasted), and fully adhered membranes. Roof decks included concrete, steel, and lightweight insulating concrete.

Team 3 Members

Ross Robertson, Report Writer, Photographer
Peter Garrigus, Data Recorder
André Desjarlais, Captain
Arthur Sark, Sample Collector

The following people also participated on one or more of the investigation days.
Warren French, Photographer
Dave Roodvoets Data Recorder
Curtis Andrews, Observer
Sal Bucolo, Observer

SUMMARY OBSERVATIONS

Wind-related damage observed on the nine roofs ranged from minor to extensive. Noted damage included membrane punctures/tears, loss of edge metal, broken securement plates, pull-over of securement plates/fasteners, and at one location, near complete displacement (blow-off) of the roof system.

The nine roofs exhibited some similarities in wind damage initiation points, damage progression, and the conditions associated with such damage.

- Initiation points of wind damage included the following:
  - — Billowing of membranes and base flashings (roof system pressurization).
  - — Lifting of edge metal and/or loss of edge securement.
  - — Puncturing/tearing of membrane from wind-borne debris and/or equipment.
  - — Release of steel deck panels from attachment points.

- Scenarios of how wind damage progressed included these:
  - — Wind-borne debris punctures membrane, roof system pressurizes through punctures, membrane billows, and then tears.
  - — Perimeter membrane billows, roof edge metal and/or nailers lift up, base membrane separates/tears at seams, membrane tears around plates/fasteners and then peels back.
  - — Edge metal bends upward, edge metal attachment fails and/or nailers lift, then base membrane separates/tears at seams, fastener plates break and/or membrane tears around plates/fasteners, then membrane peels back.
  - — Edge metal bends upward, edge metal attachment fails and/or nailers lift, then membrane wall flashings separate.

— Membrane at scupper opening billows, wall/base/scupper terminations fail, roof membrane continues to billow and then tears.

- Conditions most often leading to damage included:
  — Roof construction types that varied from industry standards.
  — Edge metal and wood nailer securement that was less stringent than current ANSI/SPRI ES-1 design standards.
  — No increased frequency of mechanical attachment in perimeters and/or corners to compensate for increased loads as specified in ASCE 7 and FM-1-29.
  — Openings that allowed roofing system pressurization.

Recommendations for enhancing wind resistance of roof coverings, based on Team 3 observations, include these:

- Design/construct roof coverings in accordance with available high-wind design guidelines (e.g., ASCE-7, ANSI/SPRI ES-1, RP-4, FM Global LPDS) and roof material manufacturers' recommendations.
- Require proper securing of rooftop equipment that otherwise may become wind-borne debris.
- Design/construct roof coverings to limit air infiltration between roof coverings and decks.
- Design/construct roof covering details that specifically enhance performance at scupper openings.

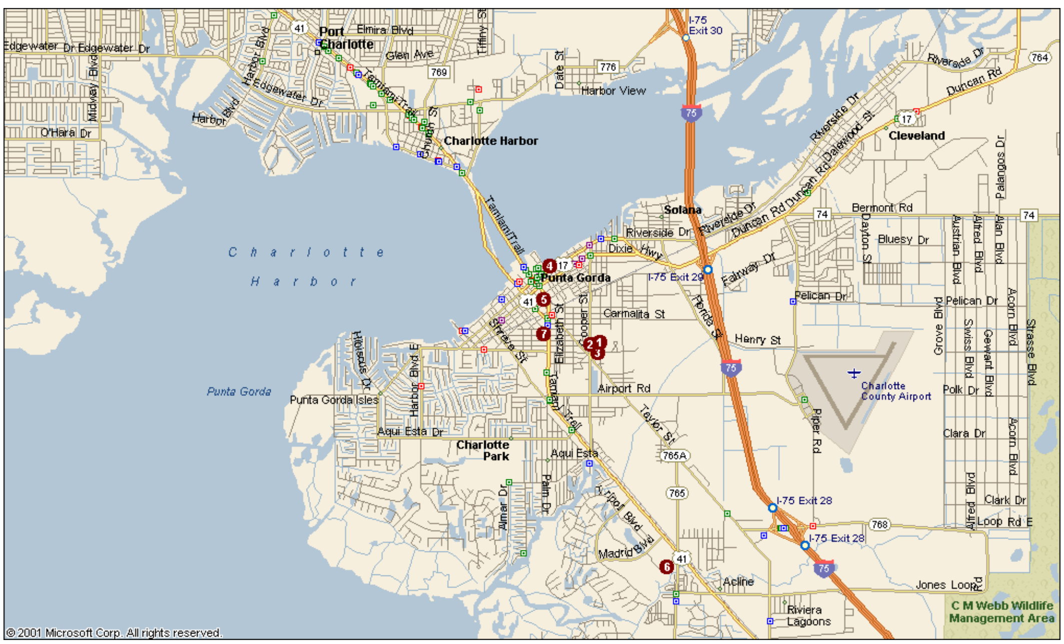


Figure 1. Locations of sites 1–7.

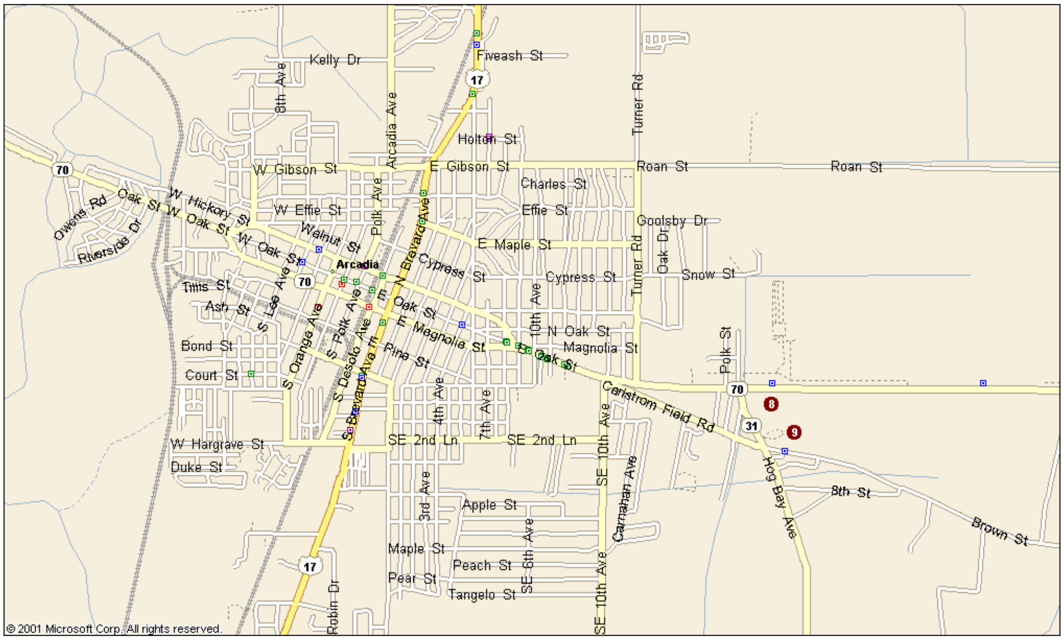


Figure 2. Locations of sites 8 and 9.

Individual Roof Reports

The following are descriptive summaries of observations and conclusions for each roof observed. Refer to photographs at the end of this section for additional information.

3.01 Charlotte County Health Department, Main Roof, 512 E. Grace St., Punta Gorda

TYPE OF STRUCTURE—Institutional facility

EXPOSURE—B

ROOF TYPE—Mechanically attached reinforced polyvinyl chloride (PVC)

ROOF HEIGHT—13 ft.

ROOF SLOPE—0–¼":12"

ROOF DECK—Lightweight concrete with steel form pan

WIND SPEED—140–150 mph

CONSTRUCTION SUMMARY—Low-rise (13 ft. high) building with very few openings (none of which were breached). Roof assembly, installed about 1988, was mechanically attached through polyisocyanurate insulation and lightweight insulating concrete with embedded expanded polystyrene (EPS) boards and secured into a steel form pan assembly. Roof membrane attachment utilized screws and plastic fastening plates through the membrane tab formed on the inside of factory-manufactured seams. Screws and plates were 12 in. o.c., in rows 58 in. o.c. across the field. Fastening at roof perimeter and corners was the same as in the field. Parapet height was typically 24 in.

NOTED DAMAGE—Moderate. Wind-related damage was limited to several punctures through the reinforced PVC membrane, and total damage was minimal (less than 1%).

DAMAGE INITIATION AND PROPAGATION—Wind-borne debris, consisting of tree limbs and building materials, was abundant on the roof and along the leeward side of the building (refer to photos 3-01-1 and 3-01-2). Damage did not appear to spread from this area.

3.02 Charlotte County Health Dept., West Roof, 512 E. Grace St., Punta Gorda

TYPE OF STRUCTURE—Institutional facility

EXPOSURE—B

ROOF TYPE—Mechanically attached reinforced PVC

ROOF HEIGHT—13 ft.

ROOF SLOPE—0–¼":12"

ROOF DECK—Lightweight concrete with steel form pan

WIND SPEED—140–150 mph

CONSTRUCTION—Low-rise (13 ft. high) building in Exposure B with very few openings (none of which were breached).

SUMMARY—PVC roof assembly, installed about 1988, was mechanically attached through polyisocyanurate insulation and lightweight concrete insulating concrete with embedded molded EPS boards and secured into a steel form pan assembly. PVC membrane attachment utilized screws and 3-in.-diameter plastic fastening plates through the membrane tab formed on the inside of factory-manufactured seams. Screws and plates were 12 in. o.c., in rows 58 in. o.c. across the field of the roof. Fastening at roof perimeter and corners of the roof was the same as in the field. Parapet height was typically 24 in.

NOTED DAMAGE—Minor. Wind related damage was limited to several punctures through the reinforced PVC membrane, and total damage was minimal (less than 1%).

DAMAGE INITIATION AND PROPAGATION—An air-conditioning unit was blown over and onto the roof surface, resulting in tears (refer to photos 3-02-1 and 3-02-2). In general, wind-borne debris, consisted of tree limbs and building materials. Debris was significant on the roof and along the leeward side of the building. Damage did not appear to spread from this area.

3.03 Charlotte County Health Dept., Upper Roof, 512 E. Grace St., Punta Gorda

TYPE OF STRUCTURE—Institutional facility

EXPOSURE—B

ROOF TYPE—Mechanically attached reinforced PVC

ROOF HEIGHT—18 ft.

ROOF SLOPE—0–¼":12"

ROOF DECK—Lightweight concrete with steel form pan

WIND SPEED—140–150 mph

CONSTRUCTION SUMMARY—Low-rise (18 ft.) building with very few openings (most of which were breached). Roof assembly, installed about 1988, was mechanically attached through polyisocyanurate insulation and lightweight deck assembly. PVC membrane attachment utilized screws and 3-in.-diameter plastic fastening plates through the membrane tab formed on the inside of factory-manufactured seams. Screws and plates were 12 in. o.c., in rows 58 in. o.c. across the field of the roof. Fastening at roof perimeter and corners of the roof was the same as in the field. Parapet height was typically 24 in.

NOTED DAMAGE—Extensive. The PVC base membrane was nearly 100% blown off the structure, while more than 95% of roof insulation remained in place. The PVC parapet membrane remained in place on north and east walls, although only about 5% of the aluminum coping survived (refer to photos 3-03-1 and 3-03-2). Most membrane and insulation attachment screws also remained in place. Most plastic fastener plates (for roof membrane attachment) were broken. Some plastic insulation fastener plates were broken (refer to photo 3-03-3). Aluminum coping was inadequately fastened with lead expansion anchors and without cleats. Coping was fastened at an average of 48 in. o.c. on the parapet exterior and 36 in. o.c. on the interior side. Most coping was displaced, while remaining portions were distended on the parapet exterior, from wind uplift.

DAMAGE INITIATION AND PROPAGATION—Because of the near-complete removal of coping metal and the fact that wall membrane remained in place on north and east walls, it appears that loss of the coping led to wind pressurization and subsequent roof membrane loss.

ADDITIONAL COMMENTS—This roof likely would have survived intact if edge detail attachment had been more secure.

3.04 Charlotte County Government High-Rise Facility, Main Roof, 350 East Marine, Punta, Gorda

TYPE OF STRUCTURE—High-rise office facility

EXPOSURE—C

ROOF TYPE—Mechanically attached reinforced PVC

ROOF HEIGHT—70 ft.

ROOF SLOPE—0–¼":12"

ROOF DECK—Concrete

WIND SPEED—140–150 mph

CONSTRUCTION SUMMARY—High-rise (70 ft.) building in Exposure C with many openings (some of which were breached). The roof assembly, installed about 1999, was mechanically attached through lightweight insulating concrete (with embedded EPS boards) and secured into concrete deck. The PVC membrane attachment utilized spikes and 2-3/8-in.-diameter barbed metal fastening plates in the membrane seam overlap. Spikes and plates were 16 in. o.c., in rows 48 in. o.c. in the field of the roof and 12 in. o.c., in rows 24 in. o.c. along the 12-ft.-wide perimeter. Corners were fastened in the same way as the perimeter. There was a 2-ft.-wide exterior overhang along the parapet. Through-wall scuppers were installed in the parapet (refer to photo 3-04-1).

NOTED DAMAGE—Moderate. Specific wind-related damage was limited to the peeling of the wall and roofing membrane in the southwest corner. Overall damage included many punctures from wind-borne debris, primarily consisting of rooftop equipment components. It was estimated that over 50% of the air-handling equipment was blown off this roof (refer to photo 3-04-3). The lightning protection system (LPS), while remaining on the roof, became loose and damaged the membrane system when LPS cables were whipped by winds. (refer to 3-04-4).

DAMAGE INITIATION AND PROPAGATION— Air infiltration at the through-wall scupper, intensified by the overhang and outreaching corner condition, billowed and then detached the roof membrane in the SW corner (refer to photos 3-04-5 and 3-04-6).

ADDITIONAL COMMENTS—This roof and building held up surprisingly well considering the significant damage occurring in the immediate vicinity.

3.05 Charlotte County South Annex, Main Roof, 410 Taylor Street, Punta Gorda

TYPE OF STRUCTURE—Office building

EXPOSURE—B

ROOF TYPE—Mechanically attached reinforced PVC

ROOF HEIGHT—13–18 ft.

ROOF SLOPE—0–¼":12"

ROOF DECK—Steel

WIND SPEED—140–150 mph

CONSTRUCTION SUMMARY—Low-rise (13–18 ft.) building in Exposure B with moderate number of openings (none of which were breached). The roof assembly, installed about 1999, was mechanically attached through 3½-in. polyisocyanurate insulation and secured to the deck. PVC membrane attachment utilized screws and metal fastening plates in the seam overlap. Screws and 2-in. barbed metal plates were 12 in. o.c., in rows 48 in. o.c. in the field of the roof. Screws and 2-in. barbed metal plates were 12 in. o.c., in rows 24 in. o.c. along the 4-ft.-wide perimeter of the roof. Corners were fastened in the same way as the perimeter. There was a roof-level metal roof edge at all perimeters.

NOTED DAMAGE—Moderate. Nailers, roof edge metal, and PVC roof membrane were displaced in the southeast corners of the south-side portions on lower roofs (refer to photos 3-05-1 and 3-05-2). Only minor impact damage occurred from wind-borne debris.

DAMAGE INITIATION AND PROPAGATION—Perimeter membrane billowed, roof edge metal and/or nailers were lifted, and then the base membrane separated/tore at seams or around plates/fasteners, leading to displacement. Most roof insulation remained in place. Failed 2×6 nailers were fastened with 16D common nails spaced approximately 2 ft. o.c. only along the inside edge of the nailer (refer to photo 3-05-3). The PVC roof membrane held at either the first or second perimeter row of attachment.

ADDITIONAL COMMENTS—More secure attachment of nailers and metal work likely would have prevented roof system failure.

3.06 Large Retail Building, Burnt Stores Road, Punta Gorda

TYPE OF STRUCTURE—Retail building

EXPOSURE—C

ROOF TYPE—Ballasted and loose-laid, unreinforced EPDM

ROOF HEIGHT—16–22 ft.

ROOF SLOPE—0–¼":12"

ROOF DECK—Steel

WIND SPEED—140–150 mph

CONSTRUCTION SUMMARY—Low-rise (16–22 ft.) building in Exposure C, with very few openings (none of which were breached). The ballasted portions of the roof assembly were covered with ASTM Type 3 stone ballast at an estimated 13 lb. per ft.[2] Roofs were installed over 2½-in. EPS boards, which were placed over ¾-in. perlite board. The perlite was fastened to the deck using screws and metal fastening plates at a rate of one fastener per square foot. Parapet height was typically 12–24 in. along the west, north, and east perimeters. Along the south perimeter was a roof-level metal gravel stop roof edge.

NOTED DAMAGE—Extensive: 10% of the roof along the south and west sides of the building. Gutters, edge metal, perimeter nailers, the anchor course of the concrete masonry unit (CMU) wall, steel decking, copings, parapet membrane, roof insulation, and EPDM roof membrane were displaced at the south perimeter, southeast and southwest roof corners.

DAMAGE INITIATION AND PROPAGATION—Air infiltrated at uplifted gutters along south perimeter and at copings at southeast and southwest roof corners. At the roof edges, gutters and edge metal continued to lift, and the roof membrane billowed until nailers and/or the anchor course of the CMU wall were displaced; then the roof membrane, insulation, and additional ballast were displaced (refer to photos 3-06-1 through 3-06-4). At copings, the wall membrane peeled, the roof membrane billowed, the ballast was displaced, and sections of coping popped off, followed by displacement of the roof membrane, insulation, and additional ballast (refer to photo 3-06-5).

3.07 Commercial Office Building, 150 MacKenzie, Punta Gorda

TYPE OF STRUCTURE—Office building

EXPOSURE—B

ROOF TYPE—Fully adhered single-ply reinforced thermoplastic polyolefin (TPO) membrane

ROOF HEIGHT—16 ft.

ROOF SLOPE—½–1":12"

ROOF DECK—Steel

WIND SPEED—140–150 mph

CONSTRUCTION SUMMARY—Low-rise (16 ft.) building with many openings [one of which was breached on main (east) damaged side]. The roof assembly, installed after 1999, was mechanically attached through 2½-in. polyisocyanurate insulation into decking. The TPO membrane attachment utilized screws and metal fastening plates in the membrane seam. Screws and 2-in. barbed metal plates were 6 in. o.c., in rows 10 ft. o.c. in the field of the roof. Screws and 2-in. barbed metal plates were 6 in. o.c., in rows 3½ ft. o.c. along the 7-ft.-wide perimeter of the roof. Corners were fastened in the same way as the perimeter. Parapet height ranged from 2 to 24 in. along the south, west, and north perimeters. Along the east perimeter was a roof-level metal edge and gutter.

NOTED DAMAGE—Moderate. Gutters and edge metal were damaged or missing and the roof membrane had been displaced along the east perimeter. Roof membrane displacement stopped at the row of fasteners closest to the edge, and it had been reattached prior to this inspection. Coping was damaged or displaced at the south perimeter and southeast corner. Additional wind-related damage included many punctures through the roof membrane from wind-borne debris.

DAMAGE INITIATION AND PROPAGATION—Along the east perimeter, air infiltrated at uplifted gutters; gutters and roof edge metal continued to lift, and the roof membrane billowed until most metal work was displaced, causing the roof membrane to blow back from the edge. The roof membrane remained in place at the first row of perimeter attachment (refer to photo 3-07-1). At the south perimeter and southeast corner, coping sections were typically uplifted and some were completely displaced (refer to photos 3-07-2 and 3-07-3). Wind-borne debris (tree limbs and building materials) caused significant punctures (refer to photos 3-07-4 and 3-07-5).

ADDITIONAL COMMENTS—Enhancement of metal work attachment likely would have allowed this roof to fare much better.

3.08 Small Retail Building, US 70 East, Arcadia

TYPE OF STRUCTURE—Office building

EXPOSURE—C

ROOF TYPE—Fully adhered single-ply unreinforced EPDM membrane

ROOF HEIGHT—15 ft.

ROOF SLOPE—½–1":12"

ROOF DECK—Steel

WIND SPEED—130–140 mph

SUMMARY—Low-rise (15 ft.) building in Exposure C with many openings (none of which were breached). The roof assembly, installed after 1999, was fully adhered to polyisocyanurate insulation. The insulation was fastened to the deck with screws and metal insulation plates at a rate of one fastener per square foot. Perimeters and corners had no enhanced attachment. Parapet height ranged from 1½ to 5 ft. along the west, north, and east sides. Along the south side was a roof-level metal edge and gutter.

NOTED DAMAGE—Moderate. Gutter and metal edge were uplifted along the south perimeter. Coping was displaced, and some wall membrane was partially peeled from the wall.

DAMAGE INITIATION AND PROPAGATION—Along the south perimeter, wind lifted gutters, which lifted the metal edge, but damage did not propagate further (refer to photos 3-08-1 and 3-08-2). At the southeast corner and along the east perimeter, coping metal lifted and caused the wall membrane to partially peel from the wall. Peeling stopped before reaching the bottom of the wall (refer to photos 3-08-3 and 3-08-4).

ADDITIONAL COMMENTS—Enhanced metal work attachment, especially of the coping, likely would have allowed this roof to survive undamaged (refer to photos 3-08-5, 3-08-6, and 3-08-7).

3.09 Large Retail Building, 2725 Southeast Hwy. 70, Arcadia

TYPE OF STRUCTURE—Large retail building

EXPOSURE—C

ROOF TYPE—Fully adhered single-ply reinforced TPO membrane

ROOF HEIGHT—18 ft.

ROOF SLOPE—0–¼":12"

ROOF DECK—Steel

WIND SPEED—130–140 mph

CONSTRUCTION SUMMARY—Low-rise (18 ft.) building in Exposure C with few openings (none of which were breached). The roof assembly, installed in 2002, was mechanically attached through polyisocyanurate insulation and secured to the deck. Roof membrane attachment utilized screws and metal fastening plates in the membrane seam. Screws and 2-3/8 in. barbed metal plates were 12 in. o.c., in rows 6 ft. o.c. in the field of the roof. Screws and 2-3/8-in. barbed metal plates were 12 in. o.c., in rows 3 ft. o.c. along the 12 ft. wide perimeter of the roof. Corners were fastened in the same way as the perimeter. Parapet height ranged from 3–4 ft. along the west, north, and east perimeters. Along the south perimeter was a roof-level metal edge and gutter.

NOTED DAMAGE—Moderate. Along the south perimeter, the gutter lifted; a third of the gutter became completely detached and blew off. Metal edge was deflected upward where the gutter was displaced. Additional wind-related damage included many punctures through the roof membrane from wind-borne debris.

DAMAGE INITIATION AND PROPAGATION—Along the south perimeter, wind uplift deflected both gutters and metal edge. Then a third of the total gutter detached and blew across the roof, puncturing the roof membrane and breaking skylights. The broken skylights also punctured the roof membrane, but the damage did not propagate further (refer to photos 3-09-1 through 3-09-4).

ADDITIONAL COMMENTS—Enhanced attachment of guttering likely would have allowed this roof to fare much better.

3.10 Medium-size Stand-alone Retail Store, 3451 Tamiami (NW41), Port Charlotte

TYPE OF STRUCTURE—Commercial building (single story)

EXPOSURE—B

ROOF TYPE—Built-up roofing (BUR)

ROOF HEIGHT—18 ft.

ROOF SLOPE—¼":12"

ROOF DECK—Steel (22 gauge)

WIND SPEED—130–140 mph

CONSTRUCTION SUMMARY—Low-rise building (18 ft.) with large windows and a door on the east side. The fully adhered membrane was bonded to ¾-in. perlite. The perlite boards were mopped to 2½-in. polyisocyanurate insulation boards, which were screwed to the deck. The roof had parapets that ranged from 10 to 40 in. high along the north and south walls; the east parapet was 10 in. high, and the west wall parapet was 40 in.

NOTED DAMAGE—Extensive. Roof membrane, metal deck, and joists were completely peeled back from the building and deposited in an adjoining yard. There was evidence of some membrane displacement prior to the roof membrane rolling up (as it was blown back) similar to a window shade.

DAMAGE INITIATION AND PROPAGATION—It appears that the front doors blew inward with the direct force of the east wind. The building then became pressurized, causing the front windows to blow out. A resulting large opening in the east (windward) side of the building caused the entire front of the structure to lift up. This influx of internal air pressure pushed upward against the deck, causing it to peel back from the structure and become detached from the building. About 90% of the building was open to the sky. Lack of solid structural attachment to pilasters, and detached pilasters, contributed to the damage.

3.11 Medical Imaging Center, 2885 Tamami (NW41), Port Charlotte

TYPE OF STRUCTURE—Medical office building

EXPOSURE—B

ROOF TYPE—Fully adhered reinforced thermoplastic single-ply

ROOF HEIGHT—18 ft.

ROOF SLOPE—¼":12"

ROOF DECK—Varied: plywood, concrete

WIND SPEED—130–140 mph

CONSTRUCTION SUMMARY—Low-rise building of concrete masonry, with no openings in the floor beneath the deck and limited openings in the main floor. Membrane was fully adhered to wood fiber insulation boards. Most of the roof deck was concrete plank with a concrete overlay; there was one area of plywood decking. The insulation had been adhered to the deck with an asphalt mopping.

NOTED DAMAGE—Extensive. Metal coping and some wood nailers were displaced from the northeast parapet. The membrane was peeled from the wall and from about 50% of the roof, including a lower roof area. The peeling appeared to stop when the membrane tore, likely from impinging on air-handling units. Many HVAC units were displaced.

DAMAGE INITIATION AND PROPAGATION—Metal coping was dislodged. It left the edge vulnerable to wind uplift and may have acted like a sail, taking the membrane with it. Coping metal was fastened 40 in. o.c. The outer flange was not hemmed and barely covered the wood nailer. There were no cleats to secure the coping. The membrane had peeled from the windward walls and from about 50% of the roof area. The peeling action completely removed the membrane and insulation at the windward edge of the roof; farther from the wall, the insulation remained attached to the deck, but the membrane peeled from the insulation. Displaced mechanical units tore membrane that was still attached to the deck.

3.12 Telephone Exchange Building, 3391 Tamiami Rd., Port Charlotte

TYPE OF STRUCTURE—Concrete block low-rise windowless building

EXPOSURE—B

ROOF TYPES (2)—Thermoplastic single-ply; sprayed polyurethane foam (SPF)

ROOF HEIGHT—20 ft.

ROOF SLOPE—¼":12"

ROOF DECK—Steel, cementitious wood fiber

WIND SPEED—130–140 mph

CONSTRUCTION SUMMARY—Low-rise building (20 ft.) with one door/window opening on the northeast side. Differing roof assemblies were found on three roof sections: (1) a fully adhered thermoplastic single-ply membrane over a cover board, tapered polyisocyanurate insulation over a steel deck; (2) SPF over tapered isocyanurate, over wood fiber, over gypsum deck, over glass fiber form board; (3) a smaller lower section of mechanically attached thermoplastic single-ply over tapered polyisocyanurate insulation and cementitious wood fiber deck. Most areas of the building had metal edge details with gutter.

NOTED DAMAGE—Not extensive. The fully adhered thermoplastic membrane section was undamaged. The mechanically attached single-ply section was undamaged. An air-handling fan was damaged on the fully adhered roof section but did not appear to puncture the membrane. A large section of the SPF roofing was blown off, and temporary repairs had been made. The metal edge was completely gone from the SPF roof.

DAMAGE INITIATION AND PROPAGATION—Damaged section was apparently pressurized when the door failed, creating an opening. The exact sequence and pattern of damage was difficult to assess because of the temporary repairs.

PHOTOGRAPHS OF ROOF DAMAGE

3-01-1. Charlotte County facility, main roof. Wind debris is visible on roof.

3-01-2. Charlotte County facility, main roof. More wind debris remains on roof.

3-02-1. Charlotte County facility, west roof. This HVAC unit was blown over and tore the roof membrane.

3-02-2. Charlotte County facility, west roof. Surface damage from HVAC unit is noted. (Note: HVAC unit was reset on the curb shortly after the hurricane.)

3-03-1. Charlotte County facility, upper roof. PVC base membrane nearly 100% blown off roof; more than 95% of insulation remained in place.

3-03-2. Charlotte County facility, upper roof. Parapet wall PVC membrane remained in place on north and east walls, although aluminum coping was over 95% detached.

3-03-3. Charlotte County facility, upper roof. Most of the plastic fastener plates attaching the membrane were broken.

3-04-1. Charlotte County government facility, high-rise. Two-foot wide exterior overhang and through-wall scuppers were a feature of the parapet.

3-04-2. Charlotte County government facility, high-rise. This is the wind-damaged SW corner.

3-04-3. Charlotte County government facility, high-rise. It was estimated that over 50% of the air handling equipment was blown off the roof.

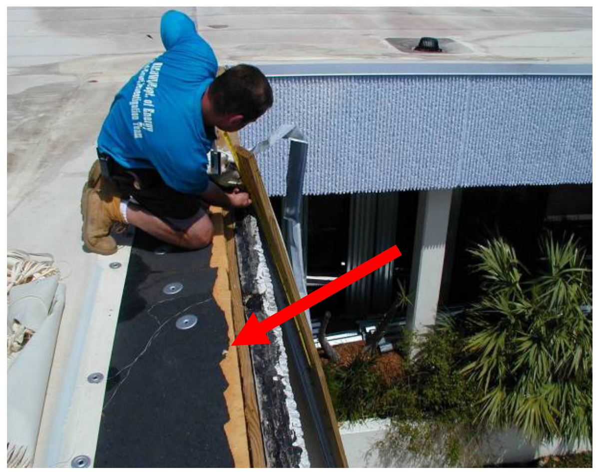
3-04-4. Charlotte County government facility, high-rise. The lighting protection system remained on the roof, but the loose cables whipped around, damaging the membrane system.

3-04-5. Charlotte County government facility, high-rise. This photo shows a scupper at the wind-damaged SW corner.

3-04-6. Charlotte County government facility, high-rise. This is the SW corner with a through-wall scupper and an overhand.

3-05-1. County Office Building. Nailers, roof edge metal, and PVC roof membrane were displaced in the SW corner of these lower roofs (location 1).

3-05-2. County Office Building. Nailers, edge metal, and PVC roof membrane were displaced in the SE corner (south-side portions, lower roofs—location 2).



3-05-3. County Office Building. Failed 2×6 nailers were fastened with 16D common nails spaced approximately 2 ft. o.c. along only the inside edge of nailer.

3-06-1. Large retail building. Uplifted gutter, roof membrane, and ballast remained in place in some locations along south perimeter.

3-06-2. Large retail building. Typical damage along south perimeter.

3-06-3. Large retail building. Top nailer attachment: 1 ft. o.c. with hot-dipped galvanized 16D nails.

3-06-4. Large retail building. The worst damage occurred at SE corner.

3-06-5. Large retail building. Damage along parapet.

3-07-1. Commercial office building. Damage along east perimeter.

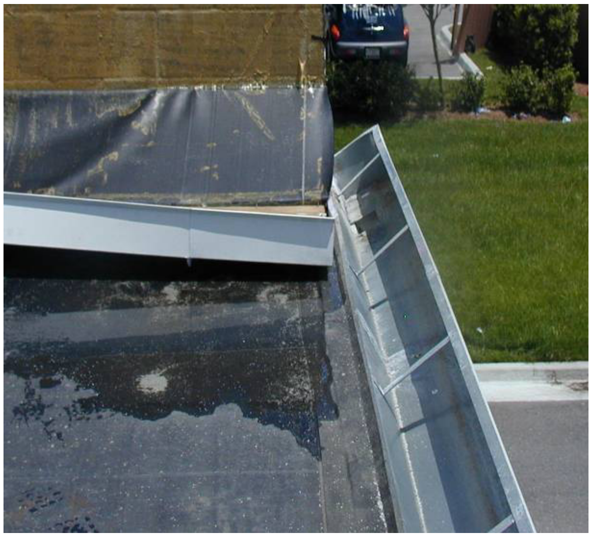
3-07-2. Commercial office building. Typical coping damage.

3-07-3. Commercial office building. Verifying coping attachment.

3-07-4. Commercial office building. Punctures from wind-borne debris.

3-07-5. Commercial office building. Debris from roofs.

3-08-1. Small retail building. Close up of windblown, deflected gutter.

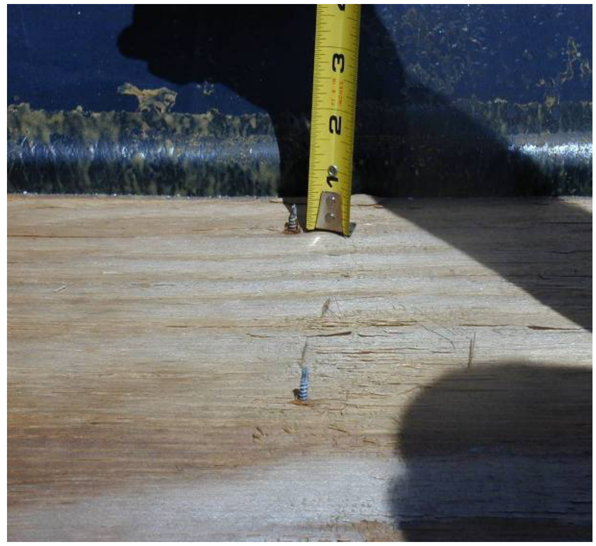


3-08-2. Small retail building. Roof view of lifted gutter and metal edge. Note roof membrane has not peeled back.

3-08-3. Small retail building. Displaced coping—north view.

3-08-4. Small retail building. Displaced coping—south view.

3-08-5. Small retail building. Coping chair with leverage attachment.



3-08-6. Small retail building. Bottom of top nailer showing screws not long enough for proper attachment.

3-08-7. Small retail building. Coping chair shows scars from shallow attachment.

3-09-1. Large retail building. Large gutters had brackets to support rain loads but were not secured to prevent uplift or displacement.

3-09-2. Large retail building. Gutter metal blew across the roof, puncturing the roof membrane and breaking skylights.

3-09-3. Large retail building. Broken skylights became wind-borne debris, puncturing roof membrane—SE view.

3-09-4. Large retail building. More broken skylights and subsequent punctured membrane—NW view.

3-10-1. Auto parts business: windward side.

3-10-2. Auto parts business. leeward side.

3-10-3. Auto parts business. Even with widespread destruction, important information can be gained, such as fastener type, location, insulation and deck.

3-11-1. Medical imaging facility. Note delamination of insulation from deck and delamination of membrane from insulation.

3-11-2. Missing edge metal, progressing to missing wood nailer.

3-12-1.Telephone exchange. This roof performed well, except for lost fan. Edges did not fail.

3-12-2. Telephone exchange. Gutter and edge details survived intact on leeward side.

HURRICANE CHARLEY: TEAM 5

OVERVIEW

Team 5 focused on low slope roofs. Within 3 days, 12 different roofs were surveyed at 10 different locations. The table provides an overview of the roofing systems surveyed.

Roofing systems surveyed by Team 5

Name	Location	Membrane type(s)
Charlotte High School	Punta Gorda, FL	Modified bitumen (MB)
Charlotte High School	Punta Gorda, FL	Mechanically attached single-ply
Publix Strip Shops	Punta Gorda, FL	MB
Boca Vista Building D	Placida, FL	Granule surface built-up roofing (BUR)
Palacio Del Sol Condominiums	Punta Gorda, FL	MB
Water Treatment Plant	Sanibel Island, FL	Gravel surface BUR fully adhered single-ply
Jerry's Shopping Center	Sanibel Island, FL	MB
Charlotte Middle School	Punta Gorda, FL	Mechanically attached single-ply
Charlotte High School	Punta Gorda, FL	MB
Cardinas	Arcadia, FL	MB Sprayed polyurethane foam (SPF) coated SPF granule surface
DeSoto County High School	Arcadia, FL	Granule surface BUR
Eckerd Drug Store	Arcadia, FL	Gravel surface BUR

Team Members

Helene Hardy-Pierce, Report Writer
Bas Baskaran, Photographer
Ken Hunt, Data Recorder
Ron Kough, Sample Collector
Stan Houston, Observer

Scope

On August 18–20, 2004, Team 5 assessed damage to low slope roofs in the Florida communities of Punta Gorda, Placida, Sanibel Island, and Arcadia. This report contains narrative summaries of observations and findings for each individual roof surveyed, followed by a summary of observations and assessments from Team 5.

Although most areas viewed by the team sustained major structural damage, the following general observations were made about the various material types.

INDIVIDUAL ROOF REPORTS

5.01 Charlotte High School, 1250 Cooper St., Punta Gorda

TYPE OF STRUCTURE—School

EXPOSURE—C

WALL CONSTRUCTION—Concrete block with minimal wall/window openings

ROOF TYPE—Metal roof deck. The roof is approximately 5,000 ft. and has a low-profile metal edge consisting of a single-piece fascia.

ROOF PITCH—0–¼":12"

ROOF DECK—Steel

WIND SPEED—140–150 mph

CONSTRUCTION—One story building approximately 18 ft. high with metal roof deck; mechanically attached insulation with a granule surface MB membrane. Roof was approximately 5,000 ft^2 and has a low profile metal edge consisting of a single piece fascia.

NOTED DAMAGE—Wind-related damage was limited to the edges and around penetrations; there was wind-borne debris damage to the field of the roof from displaced heating, ventilating, and air-conditioning (HVAC) equipment. Approximately 20 ft. of the SW corner exhibited fastener back-out.

DAMAGE INITIATION AND PROPAGATION—Winds tore/displaced the metal edging from the blocking for approximately 20 ft. of the 330 ft. of metal edge; it became detached and bounced across the rooftop HVAC equipment, leaving HVAC curbs open in the interior.

ADDITIONAL COMMENTS—The adjacent lower roof appeared to be a very old 300/350 Grace roofing membrane, and it had incurred damage consistent with wind-borne debris damage. Wind lifted an HVAC unit 35 ft. across the inspected roof, over a 10 ft. courtyard, to land on a lower ethylene propylene diene monomer (EPDM) roof.

5.02 Charlotte High School, 1250 Cooper St., Punta Gorda

TYPE OF STRUCTURE—School

EXPOSURE—C

WALL CONSTRUCTION—Concrete block with minimal wall/window openings

ROOF TYPE—Mechanically attached single-ply

ROOF PITCH—0–¼":12"

ROOF DECK—Steel

WIND SPEED—140–150 mph

CONSTRUCTION—One story building approximately 15 ft. high; lightweight insulating concrete (LWIC) deck over metal pan; mechanically attached polyvinyl chloride (PVC) single-ply membrane fastened 12 in. on-center (o.c.) in rows spaced 53 in. apart. Roof was approximately 6,500 ft^2 with a single-piece gutter edge on all four sides.

NOTED DAMAGE—Wind-related damage was limited to punctures caused by wind-borne debris. Approximately 5% of the roof was damaged by punctures (22 individual punctures noted); evidence of fastener back-out; approximately 5% of the metal edge was damaged.

DAMAGE INITIATION AND PROPAGATION—Most impact/missile damage occurred in the SE corner and east side. Metal damage to SE corner. One small vent unit was displaced from the curb, yet it was still attached to its electrical source.

ADDITIONAL COMMENTS—Roof vent was attached with only one fastener per side (see photos for additional information).

5.03 Publix Strip Shops, 2310 South Tamiami Trail, Punta Gorda

TYPE OF STRUCTURE—Strip shopping center

EXPOSURE—C

WALL CONSTRUCTION—Concrete block with minimal wall/window openings on three sides; one side has 40–60% windows/doors.

ROOF TYPE—MB

ROOF PITCH—0–¼":12"

ROOF DECK—Steel

WIND SPEED—140–150 mph

CONSTRUCTION—One story building approximately 5,000 ft^2 with a 72-in. parapet on the store front side, a 60-in. shared wall on one side, a 36-in. parapet on the third side, and a gutter edge along the back side. Metal roof deck with a granule surface MB membrane over a venting base sheet directly over mechanically attached insulation.

NOTED DAMAGE—Wind-related damage was limited to punctures (four total) caused by wind-borne debris and HVAC panels. Extensive damage to fully adhered parapet wall covering. Approximately 5% of the metal coping cap was lifted/damaged.

DAMAGE INITIATION AND PROPAGATION—Front fascia of tall parapet wall had extensive damage to fully adhered EPDM wall flashing. Metal standing seam roof showed some damage. Winds left the wall flashings hanging in sheets with no attachment to the underlying plywood substrate.

ADDITIONAL COMMENTS—Membrane sustained little damage, as did metal edging.

5.04 Boca Vista Building D, 14555 Gasparilla Road, Placida

TYPE OF STRUCTURE—Condominium

EXPOSURE—C

WALL CONSTRUCTION—Stucco; approximately 45% of the walls had openings on all sides

ROOF TYPE—Granule surface BUR

ROOF PITCH—1/8":12"

ROOF DECK—Poured concrete

WIND SPEED—130–140 mph

CONSTRUCTION—Six story building; stucco wall construction with a poured concrete roof deck. Roof was surrounded by significant amounts of standing seam metal roofing. Granule surface BUR system was over mopped-in-place perlite insulation. Roof was approximately 3,700 ft^2 with a 5-ft. parapet wall on all sides, capped with a single piece of metal coping.

NOTED DAMAGE—Wind-related damage was limited to approximately 5% of the wall/parapet cap and underside of soffit. No damage to the field of the roof.

DAMAGE INITIATION AND PROPAGATION—Minimal damage that was caused by loose metal.

ADDITIONAL COMMENTS—Design and installation of many individual HVAC units that were mounted on rooftop stands was excellent. No movement was apparent for any of the HVAC units.

5.05 Palacio Del Sol Condominiums, Building 2, 1500 Park Beach Circle, Punta Gorda

TYPE OF STRUCTURE—Condominium

EXPOSURE—C

WALL CONSTRUCTION—Approximately 50% of walls had openings on all sides

ROOF TYPE—MB

ROOF PITCH—1/8":12"

ROOF DECK—Concrete

WIND SPEED—140–150 mph

CONSTRUCTION—Seven story building approximately 80 ft. high with a poured concrete roof deck followed by a lightweight concrete pour. Granule surface MB membrane was installed over a mechanically attached base ply and two intermediate ply sheets. Roof was approximately 9,000 ft^2 with parapet above, which was covered with a metal coping cap. Areas of roof were under a swimming pool deck. The roof parapet varied from 2 to 4 ft. on all sides.

NOTED DAMAGE—Significant metal edge damage (>50%) was accompanied by detachment of wood nailers (10% of wood nailers were detached). Another area of damage was under the overhang of the sundeck, caused by collapse of the sundeck support. The field of the roof was in good condition with less than 5% damage from impact/HVAC equipment.

DAMAGE INITIATION AND PROPAGATION—Edge system and loss of attachment of both nailers and metal coping cap; collapse of stucco underside of sundeck onto roof membrane; HVAC equipment.

ADDITIONAL COMMENTS—Surrounding buildings evidenced severe impact damage, particularly to tile systems.

5.06(a) Water Treatment Plant, Donak Ave., Sanibel Island

TYPE OF STRUCTURE—Single story building

EXPOSURE—C

WALL CONSTRUCTION—Concrete block; wall and window openings 20–40% of building

ROOF TYPE—Single-ply membrane

ROOF PITCH—0–¼":12"

ROOF DECK—Steel

WIND SPEED—100–110 mph

CONSTRUCTION—One story building approximately 15 ft. high. Fully adhered thermoplastic polyolefin membrane over mechanically attached iso insulation. Roof was approximately 1,400 ft^2 with a gutter edge.

NOTED DAMAGE—The edge system sustained less than 20% damage and one puncture in the membrane.

DAMAGE INITIATION AND PROPAGATION—Metal edge and wind-borne debris.

ADDITIONAL COMMENTS—Membrane and insulation attachment was in good condition.

5.06(b) Water Treatment Plant, Donak Ave., Sanibel Island

TYPE OF STRUCTURE—Single story building.

EXPOSURE—C

WALL CONSTRUCTION—Concrete block; wall and window openings 20–40% of building

ROOF TYPE—Gravel surface BUR

ROOF PITCH—0–¼":12"

ROOF DECK—Steel

WIND SPEED—100–110 mph

CONSTRUCTION—One story building approximately 20 ft. high. Gravel surface BUR over an unknown substrate. The roof was approximately 1,950 ft^2 with a gutter edge.

NOTED DAMAGE—The edge system sustained less than 20% damage. A minimal area in the field of the roof showed wind scour of gravel surfacing.

DAMAGE INITIATION AND PROPAGATION—Metal edge; unable to determine whether the wind scour was from this wind event; however, loose gravel was noted on the adjacent granule surface membrane.

5.07 Jerry's Shopping Center, 1700 Periwinkle Way, Sanibel Island

TYPE OF STRUCTURE—Shopping center

EXPOSURE—C

WALL CONSTRUCTION—Stucco exterior; 40–60% of exterior walls had window/door openings

ROOF TYPE—MB

ROOF PITCH—0–¼":12"

ROOF DECK—Steel and tongue-and-groove wood

WIND SPEED—100–110 mph

CONSTRUCTION—A single story building approximately 25 ft. high with steel and tongue-and-groove wood decks. The roof was a granule surface MB membrane installed over 2-ply sheets mopped to mechanically attached perlite. The roof size was approximately 44,000 $ft.^2$ with a single piece of low-profile metal edge.

NOTED DAMAGE—Less than 1% of the field of the roof was scuffed and punctured by wind-borne debris and HVAC equipment moving on roof; there was little damage to roof vents, and less than 5% of the metal edge was displaced.

DAMAGE PROPAGATION—The metal edge, and HVAC equipment coming off the curbs.

COMMENTS—The front perimeter of this building had a mansard with asphalt shingles; most damage to these sections was the loss of hip and ridge shingles at the NW corner of the building.

5.08 Punta Gorda Middle School, Building 1, Punta Gorda

TYPE OF STRUCTURE—School

EXPOSURE—B

WALL CONSTRUCTION—Concrete block walls; 20–40% of the exterior walls had windows/openings

ROOF TYPE—Single-ply membrane

ROOF PITCH—0–¼":12"

ROOF DECK—LWIC

WIND SPEED—140–150 mph

CONSTRUCTION—One story building with LWIC poured over metal pans. Two different areas each had mechanically attached single-ply membranes—one directly over a separator layer (Area A) to the lightweight deck and one mechanically attached with insulation in a recover system (Area B). A third roof surveyed (Area C) was on the gymnasium, which had a recover of mechanically attached single-ply membrane with iso insulation over an existing membrane, applied over a LWIC deck, poured over a metal pan. All roof areas had low-profile metal edges. The roof size was approximately 100,000 ft^2.

NOTED DAMAGE—

> Area A—25% of the roof membrane peeled off onto itself and the field of the roof incurred significant damage from wind-borne debris.
>
> Area B—Approximately 40% of the edge of the roof lifted and peeled onto the membrane; 10% of the field of the roof incurred significant wind-borne debris damage; fastener withdrawal and insulation shifting occurred on approximately 10% of the field of the roof.
>
> Area C—Approximately 10% of the roof lost both membrane and deck (open to gym below) with another 15% of the roof losing membrane. Significant damage from wind-borne debris and loss of mammoth HVAC units from curbs. One unit was "perched" 50 ft. above the ground at the edge of the roof; it displaced approximately 20 ft. and was held on the roof by an electrical connection.

DAMAGE INITIATION AND PROPAGATION—Damage was caused from wind-borne debris and loss of rooftop equipment and metal edges. The loss of metal edges was prevalent.

ADDITIONAL COMMENTS—Severe water intrusion occurred into the roofing systems (all three areas) and interior space. The rooftop condition was very poor with large amounts of debris. Nailers were inadequate, and much of the debris had fasteners puncturing membranes.

5.09 Charlotte High School, Port Charlotte

TYPE OF STRUCTURE—School

EXPOSURE—C

WALL CONSTRUCTION—Concrete block; approximately 60% of the walls had windows/openings

ROOF TYPE—MB

ROOF PITCH—0–¼":12"

ROOF DECK—Gypsum

WIND SPEED—120–130 mph

CONSTRUCTION—One story classroom building with a gypsum roof deck. The roof membrane was a granule surface MB mopped over multiple-ply sheets that were installed over three layers of tapered iso insulation with a ¾-in. perlite coverboard. All layers were mopped to a nailed base sheet. The roof was approximately 5,400 ft.^{2} with a low-profile metal edge.

NOTED DAMAGE—The roof sustained a 90% loss of roof membrane, leaving perlite insulation in place.

DAMAGE INITIATION AND PROPAGATION—The loss of membrane started at the metal edge on the SW corner. Nailers consisted of four 1×4 boards nailed together; wood appeared to be mismatched together to form the edge of the roofing system.

ADDITIONAL COMMENTS—Complete loss of the membrane occurred, causing a 100% water intrusion into classrooms below. A significant loss of windows in the classroom occurred.

5.10 Cardinas, 210 W. Magnolia, Acadia

TYPE OF STRUCTURE—Low-rise supermarket

EXPOSURE—B

ROOF TYPE—Adhered granule surface MB

ROOF PITCH—½":12" (a section of ¼":12")

ROOF DECK—Cementitious wood fiber

WIND SPEED—130–140 mph

CONSTRUCTION—Low-rise cement block construction with glassed–breached entry area, and window section on NW side with separate dock doors on SE side. The roof had a single slope to a 16-ft. peak on the north side, three slopes on the south side, a ½":12" slope on the north side and upper section of the south side, followed by a section of ¼":12" slope. All of these sections were roofed with granular surface MB. A small older section had a mechanically attached single-ply membrane. Downslope from the MB was a zero-slope section roofed with a mechanically attached thermoset single-ply membrane.

NOTED DAMAGE—Approximately 10% of the roof membrane was blown off. The north section had membrane loss and deck loss. This was inward from the breached window wall and near the peak of the roof. Edge metal was displaced in several areas not related to the major membrane loss. The edge metal used to secure the single-ply roof was detached from the nailer. Some deck in this area was blown off, and the remaining deck in the area appeared quite unstable. Some membrane was displaced but had been temporarily reattached.

DAMAGE INITIATION AND PROPAGATION—Most of the MB membrane loss was due to the breaching of the window, which created an overpressure in the building that blew both the deck and membrane off. Loss of the deck and membrane opened a significant hole and allowed water entry and subsequent damage to the contents. There were also missile impacts though the MB membrane. Inadequate metal thickness and too few cleats that appeared to be made from 26-gauge metal were the primary causes of the roof damage on the single-ply.

5.11 DeSoto County High School, Turner Road, Arcadia

TYPE OF STRUCTURE—Concrete walled gymnasium

EXPOSURE—C

WALL CONSTRUCTION—Concrete

ROOF TYPE—Gravel surface BUR

ROOF PITCH—½":12"

ROOF DECK—Lightweight concrete over steel pan

WIND SPEED—130–140 mph

CONSTRUCTION—This 40-ft.-high gymnasium was used as a shelter during Charlie, although it was not designated as a shelter. The building is of substantial construction with concrete walls and a lightweight concrete deck. There was only one exterior fire escape door that led to the outside. It reportedly was closed during the storm. Primary access was through the corridors of the adjacent building. The entire complex with several roof areas totaled more than 1,200 squares. The roof area of this section was about 200 squares; it had a stone surface 4-ply BUR. The membrane was attached to a lightweight concrete deck with mechanical fasteners.

NOTED DAMAGE—Extensive to none, in different areas. A large section of the gymnasium roof (over 40% of the membrane) blew off during the storm when about 400 people were inside. This released a large volume of water that spread across most of the school complex. The roof and roof deck over the cafeteria, which was on the opposite side of the building, was also blown off and a large amount of water entered. Other than some limited edge metal damage, there was no damage to about 1,000 squares of roof on adjacent parts of the structure. These sections were all BUR membrane roofs appearing to be of the same construction as the sections that were blown off.

DAMAGE INITIATION AND PROPAGATION—The gymnasium roof did not appear to fail because of pressurization below the deck; the cause appears to have been purely suction force. The 2-ft. parapet in the upwind corner would have been expected to reduce the maximum uplift; however the system failed. This roof was the highest point in several miles, so it took the brunt of the hurricane’s force. The roof failure pattern was typical of the uplift forces that would be present in a cornering wind, with an L-shaped area where the membrane and insulation were blown off. As temporary repairs had been made, it was not possible to determine the sequence of failure. The cafeteria area roof, which was a substantial distance from the gymnasium roof and 20 ft. lower, was blown out in an area centered along the building side. This was directly over a large window area that was breached. In this section, the cementitious wood fiber deck and the membrane were blown off. It was reported that this section failed when the wind switched directions after the gymnasium roof blew off.

5.12 Eckerd Drug Store, Arcadia

TYPE OF STRUCTURE—Retail store

EXPOSURE—B

WALL CONSTRUCTION—Concrete block wall

ROOF TYPE—Gravel surface BUR

ROOF PITCH—½":12"

ROOF DECK—Steel

WIND SPEED—130–140 mph

CONSTRUCTION—– Typical retail store construction with block walls and steel deck and polyisoboard insulation. Building height is 25 ft. on the high end and 22 ft. on the low end. Minimum parapet height is 20 in.

NOTED DAMAGE—Minor. The roof membrane was entirely intact and not leaking. Some of the pea gravel surface was displaced and had collected in the corners of the roof adjacent to the parapet. There was no report of gravel blow-off, and none was found on the adjacent grounds. This roof would have been a total success except for coping failure in five areas. The painted metal had a continuous 24-gauge cleat. About 30% of the metal was displaced.

DAMAGE INITIATION AND PROPAGATION—Inadequate securement of the edge metal because of temporary repairs. The specific information on cleats and attachment is not available.

5.13 Turner Civic Center, Arcadia

TYPE OF STRUCTURE—Large metal building used as performance arena and a hurricane shelter

EXPOSURE—C

WALL CONSTRUCTION—Concrete block wall

ROOF TYPE—Standing seam structural metal

ROOF PITCH—1":12"

ROOF DECK—Steel

WIND SPEED—130–140 mph

CONSTRUCTION—This was a very large building used for general public meetings, concerts, horse shows, and agricultural exhibits. It was a designated hurricane shelter. Primary construction was of the metal building type with some concrete block curtain wall.

NOTED DAMAGE—Major structural failure occurred. One exposed wall collapsed and nearly half of the roof was damaged. This occurred when the building was occupied as a shelter.

DAMAGE INITIATION AND PROPAGATION—The failure is currently under investigation by several consultants. RICOWI investigations were limited and cursory.

OBSERVATIONS AND ASSESSMENTS

The following points summarize the findings of Team 5 based on 3 days of roof surveys.

- Single-piece metal edges without cleats appeared to be very prone to damage on the leading edge of the building receiving the wind.
- Adequate attachment of metal edges and underlying nailers tended to reduce the damage to metal edges from lifting and distortion.
- All membranes received most of their damage from wind-borne debris, provided that edges remained intact.
- Poor securement of rooftop equipment led to a significant percentage of punctures, damaging the roof membranes.
- Fully adhered membranes tended to have very localized damage, limited to immediate punctured areas from wind-borne debris. Mechanically attached membranes exhibited signs of “tearing” from air infiltration caused by impact damage or wind-borne debris.

PHOTOGRAPHS OF ROOF DAMAGE

5-01-1. Charlotte High School complex.

5-01-2. Loss of parapet and facade.

5-01-3. Edge metal damage on modified bitumen membrane roof.

5-01-4. Displaced air handler.

5-01-6 Displaced air handler results in open exposure to rain.

5-02-1 Displaced air handler with one fastener per side.

5-03-1. Punctured modified bitumen membrane.

5-03-2. Membrane came loose from high parapet wall.

5-04-1. Well installed air handling units, also 5-ft. parapet wall.

5-05-1. Loss of wall cladding.

5-06-1. Loss of edge metal.

5-06-2. Gravel scour from BUR.

5-08-1. Complete system including old membrane and recover foam and single-ply damage.

5-08-2. Fasteners in the bottom of the flute.

5-08-3. Damaged plastic plate.

5-08-4. Air handler on the edge. The power lines are keeping it on. Also note the repairs under way at the building in the background.

5-08-5. Note fastener pattern.

5-08-6. Corroded fastener.

5-09-1. Edge failure.

5-09-2. Recover system.

5-09-3. Total membrane peel from wood fiberboard surface.

5-09-4. Peel is stopped by drain lines and a missing air handling unit.

5-10-1. Overview showing where windows were breached and where roof damage occurred directly above windows.

5-10-2. Temporary repairs on modified bitumen roof directly over breached windows.

5-10-3. Deck and membrane blow-off on south side.

5-11-1. Coping loss.

5-11-2. Pea gravel stopped by high parapet.

5-11-3. Coping metal on roof.

5-12-1. Area of temporary repairs on gymnasium roof.

5-12-2. Area of temporary repairs.

5-12-3. Coping loss.

5-13-1. Overview of Agra-center damage.

HURRICANE CHARLEY: TEAM 6

OVERVIEW

The Metal Building Manufacturers Association (MBMA) Team 6 for Hurricane Charley was composed of MBMA representatives as well as other participants. The first day, August 18, was a general preliminary investigation and reconnaissance carried out by team members Chuck Goldsmith, Ed Ural, Frank Hogan, and Brent Woody.

Team 6 Members

The following members participated for one or more of the investigation days:
Lee Shoemaker, Report Writer, Photographer
Dave Fulton, Data Recorder
Chuck Goldsmith, Sample Collector
Curtis Andrews, Observer
Danny Brenner, Observer
Frank Hogan, Observer
Ed Ural, Observer
André Desjarlais, Sample Collector
Brent Woody, Observer

Scope

The team deployed to the Charlotte County area concentrated on documenting the performance of metal roofing. This included metal buildings and metal roofing on other forms of construction. The observations summarized in this report are based on those obtained from several extended site visits as well as drive-by observations ("street surveys"). Figure 1 shows the general investigation area and the locations of the extended site visits.

Figure 1. Location of investigation area and extended site visits.

SUMMARY OBSERVATIONS

The following general observations were made. They are similar to observations made by the Hurricane Ivan Team:

- Metal roofs that were designed and installed in the past 5 or 6 years under the newer Florida codes (those adopted after Hurricane Andrew) exhibited little or no damage. Exceptions were few, and roof damage was isolated to construction practices that varied significantly from current installation instructions published by metal roof manufacturers and/or internal pressurization from openings typically created by door/window damage or other failed accessories.
- Overhead doors had a high occurrence of damage, especially in older structures. This contributed to increased internal pressures and roof blow-off. While newer overhead doors performed much better, there is still a need to improve the door/building interface and to ensure that the tested door assemblies accurately reflect the in-place conditions.
- In an overall comparison of metal roofs over 10 years old, damage was less frequent and less extensive in through-fastened roof systems than in standing seam roofs. Improved test methods for standing seam roofs, along with higher roof load requirements, obviously account for the improved performance of standing seam roofs on the newer structures.
- When a standing seam roof on metal supports was damaged, the damage mode was almost always clip separation from the panel seam. This failure mode emphasizes the importance of the type of seam and the seaming operation.
- Most observed metal roof damage not associated with door/window failure and internal pressurization started at the eave or rake edge and progressed upward toward the ridge. Eave or rake details, such as gutter attachments and flashing, were observed to be the weak point and the point where roof failure originated in many cases.
- When standing seam roofs were installed over wood substrates, plywood appeared to be more reliable than oriented strand board (OSB) with regard to screw pull-out. Fastener type and length also may be a major factor in this type of roof application.
- Hip flashing appeared to suffer frequent failure or partial failure, even in otherwise well-performing metal roof installations.

INDIVIDUAL ROOF REPORTS

The following data were logged at various sites that were representative of the observed performance and/or interesting situations.

6.01 Deep Creek Elks Lodge, 1133 Capricorn Blvd., Deep Creek

CONSTRUCTION—Typical metal building (40×80 ft.) with front drive-through entrance canopy (see photo 6-01-1). Eave height was approximately 16 ft. and roof slope was approximately 5":12". Exposure C. The front of the building was approximately facing west. Roof construction was an 18-in. trapezoidal standing seam roof supported on Z-purlins. Z-purlins were spaced at 2½ ft. at the eaves and 5 ft. in the field of the roof (see photo 6-01-3).

NOTED DAMAGE—Roof “peeled” back on the windward (north) side along front and rear rakes. Eave strut member was damaged on the front, causing separation at the top of the wall (see photo 6-01-1). Gutter was also displaced near the roof failure location.

DAMAGE INITIATION AND PROPAGATION—It appeared that damage initiation was at the eave edge, possibly as a result of the gutter attachment detail. The standing seam roof damage propagation was due to a pull-out of the clips from the seams, with all the clips still attached to the purlins.

WIND SPEED—130–140 mph

6.02 Charlotte County Stadium, 2300 El Jobean Road (SR 776), Port Charlotte

CONSTRUCTION—Canopy supported on reinforced concrete cantilevered frames with steel tube sections spanning between frames (see photos 6-02-1 and 6-02-2). Steel deck substrate with vertical leg standing seam roof covering. The standing seam system consisted of 21-in. panels and appeared to be 26-gauge steel. The system on the first base (baseball diamond) side was attached directly to the steel deck substrate, but on the third base side, hat sections were sandwiched between them (see photo 6-02-3).

NOTED DAMAGE—On the first base side, standing seam panels were blown off, as shown in photo 6-02-3. On the third base side, a light standard failed and damaged the corner of the canopy at the point of impact, as shown in photo 6-02-2.

DAMAGE INITIATION AND PROPAGATION—Standing seam components blown off on the first base side seemed to have been weakened as a result of corrosion of the subdeck, affecting fastener securement (see inset photo 6-02-1).

WIND SPEED—120–130 mph

6.03 IMPAC University, 900 W. Marion Ave., Punta Gorda

CONSTRUCTION—This site was a campus of buildings with an assortment of metal roofing types, as shown in photo 6-03-1. The area of interest, and the only real damage that was noted, was on the windward slope of the building at the far southwest of the campus (circled on photos 6-03-1 and 6-03-2). This roof was standing seam metal panels with clips attached to a wood substrate. Half of the wood substrate was plywood and the other half OSB, as noted in photo 6-03-3. Eave height was approximately 26 ft. and roof slope was approximately 4":12".

NOTED DAMAGE—Overall, the metal roofs on this campus performed quite well. The only damage, as noted, was the standing seam roof blown off on one windward slope.

DAMAGE INITIATION AND PROPAGATION—This was a good side-by-side comparison of plywood and OSB substrate performance. On the OSB side, very few clips were left, indicating a fastener pull-out failure in the OSB. However, on the plywood side, all the clips were left, indicating that the pull-out capacity for the plywood was greater than the capacity for OSB (see photo 6-03-3).

WIND SPEED—140–150 mph

6.04 Sallie Jones Elementary School, 1230 Narranja Street, Punta Gorda

CONSTRUCTION—This school was approximately one year old. The roof construction was a standing seam system over a steel deck. The hip roof eave height was approximately 22 ft. Roof slope was 6":12".

NOTED DAMAGE—This roof performed very well, and it was one of the few schools that remained operational. The only damage noted was to the soffits, as shown in photo 6-04-3.

DAMAGE INITIATION AND PROPAGATION—Soffit panels became dislodged in a few locations.

WIND SPEED—140–150 mph

6.05 Charlotte County Airport T-Hangars, 28000 Airport Road, Punta Gorda

CONSTRUCTION—Eight T-hangar buildings were investigated. They offered a unique opportunity to compare the performance of similar buildings that were designed and erected over several decades. T-hangars have “tee” frames with a single ridge column that permits large access openings for aircraft entry through side doors. A through-fastened roof was attached to purlins spanning between cantilevered frame members. Eave height was approximately 15 ft. The width of the T-hangars was approximately 30 ft. Roof slope was approximately 1":12".

EXPOSURE—C

NOTED DAMAGE—The oldest T-hangar had anchor bolts that were severely corroded (see photo 6-05-3). This row of T-hangars was destroyed. The T-hangars that were “middle-aged” (see photo 6-05-2) also suffered significant damage, mostly due to failure of the large doors to stay in place, resulting in large internal pressures. The newest T-hangars suffered only minor impact damage to one corner and some insignificant rake trim damage. The newest T-hangars also had hydraulic lift doors that performed very well, as shown in photo 6-05-4.

DAMAGE INITIATION AND PROPAGATION—The older T-hangars suffered damage primarily as a result of corrosion and door failure. Newer T-hangar construction demonstrated improvement in the building code wind loads as well as design improvements.

WIND SPEED—140–150 mph

6.06 Central Park Medical Center, 4161 Tamiami Trail, Port Charlotte

CONSTRUCTION—This site had two identical buildings that were newly built and not yet occupied. Each building was approximately 60×75 ft. and had hip roofs with slopes of approximately 5":12". The roof was a vertical leg, 16-in.-wide standing seam over a plywood deck. The damage to the rear building (noted below) revealed more detail as to clip spacing and construction. Photo 6-06-2 shows erratic clip spacing and poor workmanship. Clip spacing in one location exceeded 9 ft. along a seam, whereas typical design calls for a maximum of 24 in. o.c.

EXPOSURE—B

NOTED DAMAGE—The front building suffered no roof damage. The rear building, however, lost roof panels on both leeward and windward slopes, as shown in photo 6-06-1.

DAMAGE INITIATION AND PROPAGATION—As shown in photo 6-06-2, clip spacing was inconsistent and much too large for the roof to obtain its design uplift potential. Also, it was observed that several different types of clips were used, another indication of poor workmanship.

WIND SPEED—130–140 mph

6.07 Harbor Walk Condominiums, 200 Harbor Walk Drive, Punta Gorda

CONSTRUCTION—This condominium complex comprises three identical 5-story buildings. The one farthest to the south, and probably more directly exposed to the path of Charley, suffered some roof damage, as shown in photos 6-07-1 and 6-07-2. The roof was covered with a standing seam vertical leg system with clips screwed into an OSB deck. Clips were spaced along the seam at 12-in. spacing, utilizing two screws per clip. Eave height was approximately 50 ft. and roof slope was 7":12".

NOTED DAMAGE—Roof panels were blown off in several areas, as shown in photo 6-07-3. In some cases, clips were still attached, indicating a clip/seam failure. In other cases, clips were pulled from the deck.

DAMAGE INITIATION AND PROPAGATION—Damage progressed from the eave upward toward the ridge, with most damage in the vicinity of the ridge.

WIND SPEED—140–150 mph

6.08 Charlotte County Extension Office, 25550 Harbor View Road, Unit 3, Port Charlotte

CONSTRUCTION—Roof height varied on this building, with a primary eave height of approximately 12 ft. Roof system was a vertical leg standing seam over a wood deck. Panel width was 16 in. and the vertical legs were 2 in.

NOTED DAMAGE—Several edge areas exhibited standing seam panel pull-off. Flashing failure also was noted.

DAMAGE INITIATION AND PROPAGATION—In some areas, there was evidence that mechanical seaming of panel ends was inadequate (see photo 6-08-3). It was not clear if this was the initiation of failure.

WIND SPEED—130–140 mph

6.09 Mosquito Control Facility, 25550 Harbor View Road, Unit 2, Port Charlotte

CONSTRUCTION—This was a large maintenance facility of typical metal building construction. It was built in 2001. Overall size was approximately 150×150 ft. with an entrance canopy in one corner and an extended service bay on one side. Eave height was approximately 20 ft. and roof slope was ¼":12". The roof was covered with a 24-in. standing seam system over Z-purlins. Clips and sub-purlins were spaced closer together in the corner than in other areas, as visible in the canopy area shown in photo 6-09-2.

NOTED DAMAGE—There was extensive pull-off of the standing seam roof, as shown in photo 6-09-3. Every clip was still attached to the purlin, indicating a pull-out failure at the seam. The doors failed on the extended service bay area as well as the vertical wall skylights.

DAMAGE INITIATION AND PROPAGATION—The standing seam roof in the canopy area was missing, likely due to negative pressure above and positive pressure below. This may have been the initiation point for further roof peel-off, since the roofing just to the side of the canopy was not affected.

WIND SPEED—130–140 mph

6.10 Waste Management, 23046 Harborview Road, Charlotte Harbor

CONSTRUCTION—These appeared to be relatively old metal buildings, although the date of construction was not determined. The building to the south is a small office building, and the building to the north is a high-bay vehicle maintenance building, as shown in photo 6-10–1. The metal roof was through-fastened on Z-purlins.

NOTED DAMAGE—The office building to the south did not appear to sustain any damage. The larger building lost roll-up doors and some roofing panels, as noted in photo 6-10–3. The roof had ridge ventilators, and one was blown off. There was also end wall corner damage, as noted in photo 6-10–2.

DAMAGE INITIATION AND PROPAGATION—The roofing damage was probably initiated by two factors. The loss of the roll-up doors would have increased internal pressure, and the loss of the ridge ventilator may have played a factor, as well.

WIND SPEED—130–140 mph

6.11 Charlotte County Fire and EMS Station #12, 2001 Luther Road, Port Charlotte

CONSTRUCTION—The pre-hurricane appearance of this fire station is shown in photo 6-11-1. The center portion is the vehicle area having a high roof with wood trusses spanning from front to back. The roof is covered with a vertical leg standing seam over a wood deck. Wood trusses were spaced at approximately 24 in. over the vehicle bays and were attached to a concrete tie-beam with anchor straps. Slope was approximately 7":12". Eave height at the center portion was approximately 20 ft., and the end portions had an eave height of approximately 12 ft.

NOTED DAMAGE—The center portion of the roof was entirely blown away from the structure, as shown in photo 6-11-2. This center section landed approximately ¼ mile away across the interstate highway. The roof was blown off in all four corners adjacent to the center of the building, as shown in photos 6-11-2 and 6-11-4.

DAMAGE INITIATION AND PROPAGATION—The blow-off of the center portion was the result of a tension failure of the tie-straps, as shown in photo 6-11-3. It was not clear if failure of the overhead doors occurred first, increasing the internal pressure. The standing seam roof failure at the four corners was apparently precipitated by the loss of the center portion that tore these panels off with it.

WIND SPEED—130–140 mph

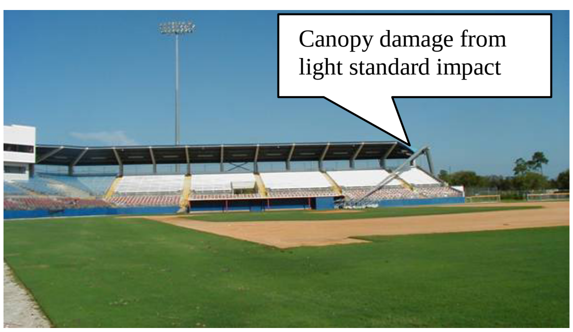
PHOTOGRAPHS OF ROOF DAMAGE

6-01-1. Deep Creek Elks Lodge. Front (windward) side showing panel displacement.

6-01-2. Deep Creek Elks Lodge. Rear (leeward) side roof damage.

6-01-3. Deep Creek Elks Lodge. Note varied purlin spacing, affecting edge uplift.

6-02-1. Charlotte County Stadium. First base canopy shows corrosion in subdeck (inset).

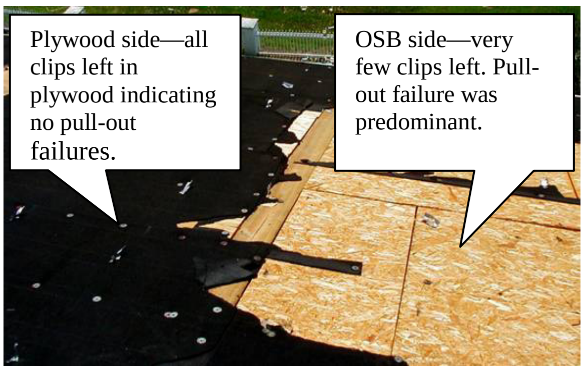


6-02-2. Charlotte County Stadium. Third base canopy damage.

6-02-3. Charlotte County Stadium. Canopy with hat sections between covering and subdeck.

6-03-1. IMPAC University. Pre-hurricane aerial photo.

6-03-2. IMPAC University. Area where roof failure occurred.

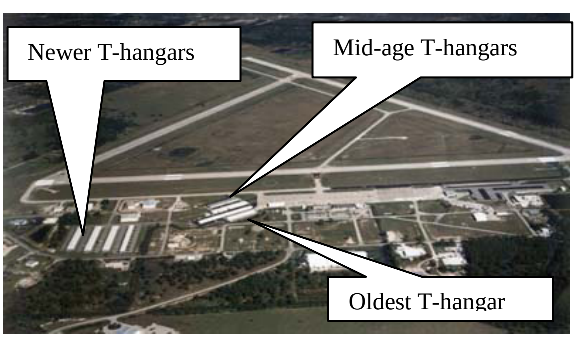


6-03-3. IMPAC University. Plywood and OSB substrate comparison, regarding holding power.

6-04-1. Sallie Jones Elementary. A roof with excellent performance.

6-04-2. Sallie Jones Elementary School. No damage noted in this photo.

6-04-3. Sallie Jones Elementary School. The only problem was some soffit failures.



6-05-1. Charlotte County Airport T-hangars. Pre-hurricane view of airport.

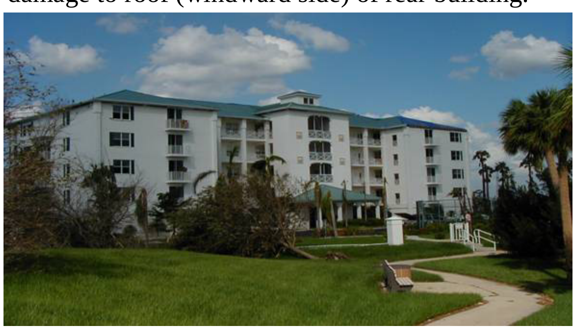
6-05-2. Mid-Age T-hangars. T-hangars (circa 1960s). Most doors were blown away or destroyed.

6-05-3. Oldest T-hangar (circa 1940s–50s). Anchor bolt failures led to total destruction.

6-05-4. Newest T-hangar. Hydraulic lift doors without damage.

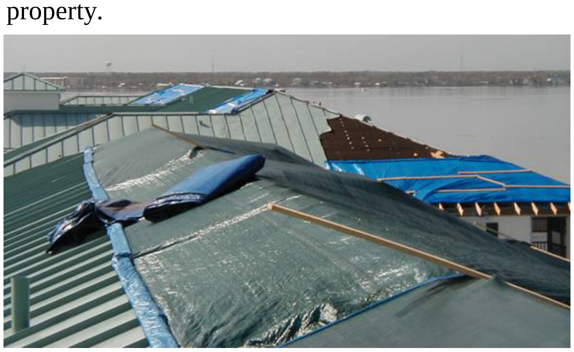
6-6-1. Central Park Medical Center. Note damage to roof (windward side) of rear building.

6-06-2. Central Park Medical Center. Note erratic clip spacing.



6-07-1. Harbor Walk condos. Windward face of property.

6-07-2. Harbor Walk condos. A closer view shows some roof damage (note arrow).



6-07-3. Harbor Walk condos. Standing seam roof damage.

6-08-1. Charlotte County Extension. Standing seam roof on office building.

6-08-2. Charlotte County Extension. Damaged standing seam panels due to poor end seaming.

6-08-3. Charlotte County Extension. Note poor end seaming.

6-09-1. Mosquito control. Failed overhead door in end bay—canopy area shown under arrow.

6-09-2. Mosquito control. Canopy area with missing panels at failure initiation point.

6-09-3. Mosquito control. This standing seam roof was peeled back over canopy and onto field of roof.

6-10-1. Waste management. Overhead vehicular door opening.

6-10-2. Waste management. End-wall damage.

6-10-3. Waste management. Standing seam roof damage.

6-11-1. Charlotte County EMS station. Pre-Charley appearance.

6-11-2. Charlotte County EMS station. View of failed center roof and corner damage (arrows).

6-11-3. Charlotte County EMS station. Roof truss tie-down anchor straps failed in tension.

6-11-4. Charlotte County EMS station. Standing seams failed at all four corners.

HURRICANE CHARLEY

STEEP SLOPE ROOF SYSTEMS

HURRICANE CHARLEY: TEAM 1

OVERVIEW

The members of Team 1 were assigned to gather data on steep slope roofing materials. The team identified the critical areas of Punta Gorda Isles, Burnt Stores, and the Harbor Heights areas of Port Charlotte for inspection. In an effort to maximize data collection, this team was divided into two sub-teams.

Team Members

The following members participated on Teams 1 and 1A for one or more of the investigation days.

Team 1:
Rick Olson, Report Writer
Warren French, Photographer
Dave Faulkner, Data Recorder/Sample Collector
Stan Houston, Observer

Team 1A:
Jerry Vandewater, Sample Collector
Reese Moody, Report Writer/Photographer
Eric Haefli, Data Recorder
Maria Luisa Rouco, Sample Collector
Ted Bowers, Observer
Bart Cox, Observer

Scope

On August 18 and 19, the two sub-teams covered the initial areas of the city of Punta Gorda, Punta Gorda Isles, and Burnt Stores. During the initial 2 days of field investigation, it became apparent that the teams would not be able to collect a significant amount of field data if they attempted to closely inspect each roof. RICOWI field coordinators agreed that quick cursory surveys would be allowed to increase the available field data for the final report. On days 3 and 4, the teams assigned to steep slope roofs were given the task of collecting sample data from entire streets. The address, roofing material, and condition of each roof were indicated. This report is a summary of those field data.

Building Construction Overview

Most of these residential structures were built in the 1970–1980 timeframe. In the Punta Gorda Isles area, there were a higher percentage of tile roofs. Since these homes were older homes, they were built before the newer codes were in force. The Burnt Stores area had an area of older structures mixed with some of newer construction. The Harbor Heights area was a mixture of structures built from the 1960s through 2005.

Roofing Materials Overview

The field teams were able to investigate roof coverings constructed of the following materials:

- Tab asphalt shingles
- Dimensional shingles

- Built-up roofing/rolled roofing
- Metal: through-fastened or standing seam metal
- Clay and concrete tile: mechanical, adhesive, and mortar-set systems

SUMMARY OBSERVATIONS

Although most surveyed areas sustained major structural damage, the following general observations were made about the various material types. These generalizations do not make judgments as to the ability of the roof design to perform, but rather to report actual field results found in perimeter areas of wind damage zones where roof trusses and roof decks were still in place.

There are many difficulties associated with trying to compare the wind resistance performance of roofing of different types and different ages. First, it is impossible to determine the exact age of a roofing material simply through visual examination. In addition, it is understood that a roofing material's ability to withstand winds is a complex interplay of many factors, such as wind speed, roof design type (e.g., gable vs. hip), surrounding terrain, direction of the strongest winds, roof slope, building height, roofing material itself, attachment method, and other variables.

Despite the limitations of cursory inspections, and the occasional inaccuracies that may result from unknowns, the following anecdotal observations were made:

3-Tab Shingles. In general, the older styles of 3-tab shingles were found on homes built prior to the 1997 wind codes. As reported in Tables 1 and 2, most of these roofs sustained major damage. The teams were not able to determine if age of materials was a factor, but the inability of shingles to remain even partially intact indicated a lack of uplift resistance.

Re-roof (Retrofit) over 3-Tab Shingles. These roofs seemed to perform similarly to 3-tab shingle roofs. Even newer architectural shingles installed over older 3-tab dimensional shingles sustained major damage. In many cases, fastener length was not sufficient to adequately penetrate the substrate.

Architectural Shingles. It was noted that structures with newer architectural shingles were relatively successful, as noted in Table 1 and 2. In many cases, these shingles appeared to have been installed within the last few years. Teams were not able to adequately correlate shingle age to its performance.

Metal Roofing. The teams were able to inspect only a few metal roofs. The majority of these were through-fastened metal roof systems with fasteners 6 in. o.c., going up-slope. While these systems appeared to remain intact, some oil-canning of individual panels was noted. (This may have been present before the hurricane and is not of structural concern.) One building with a stone-coated metal roof installed over a batten system sustained major damage—the metal tiles and battens came off together in large sections. Fastener pull-out of battens was also observed.

Concrete and Clay Tile. Since concrete and clay tiles were the predominant roofing materials in the ground-zero impact area of the storm, teams were able to inspect numerous installations. Several major methods of tile installations were observed. It was not possible to quantify and compare the performance of the attachment methods because the quantities of the various types of tile attachments are unknown.

1. Mortar Application. It is assumed that for most homes built before 1997 that were in the most severe damage path, the predominant attachment method was adhesion via mortar. This type of tile installation sustained major damage in most cases, as the tiles were found to be scattered across the roof surface. Even on roofs where tiles remained in place, teams found evidence of loose tiles. The team found that such installations allowed tiles to move as wind speed increased, resulting in tile displacement. Teams identified numerous workmanship defects that led to significant damage in this system, including mortar paddies that were too small (i.e., not the #10 trowel of mortar required) and improperly located mortar. In most cases, mortar paddies were 4–6 in. in diameter, in the centers of the tiles. This indicated that the mortar was too wet and too thin to make contact with the tile above. It also suggested lack of adequate contact with tile and/or underlayment to provide wind uplift resistance. There was evidence of loss of tile-to-mortar bonding and mortar-to-underlayment bonding at the time tiles were displaced. The high incidence of mortar tile system damage observed in the Punta Gorda area, therefore, appears to be the result of the widespread usage of the mortar attachment method, and its relatively poor performance.

2. Nail/Screw Systems. On structures built after the 1997 code changes, teams were able to find tile installations where roofs were damaged, but tiles remained intact. In the Punta Gorda area, where roofs were installed with a single screw per tile, there was evidence of partial blow-off that appeared to commence at the eave course. These roofs were 40 ft. in the air and had significant loss of hip and ridge tiles. Teams did find evidence of damage (blow-off) of the first course of tiles installed in Punta Gorda and almost 60 miles inland toward Orlando. Since there were few damaged buildings that were constructed after the newer codes took effect, teams were unable to determine why those remained intact while older ones experienced tile blow-off.

3. Adhesive Systems (non-cementitious). Adhesive-based tile installations fall into two types: single-component and two-component adhesives. Each type has detailed installation requirements (from the adhesive manufacturers) that must be followed in order to provide the proper wind uplift resistance. Since this is a relatively new installation method, teams were able to find only a few applicable structures to analyze. These structures performed well, but teams were unable to perform destructive testing to ascertain why several tile roofs sustained damage. The following observations were made:

- Improper quantities of adhesives were applied under tiles.
- In some cases, adhesive was applied in straight lines, a significant variance from adhesive manufacturers' guidelines.
- In some cases, adhesives were placed in the wrong locations, apparently in an effort to adhere two courses of tile at one time. These locations were again at odds with adhesive manufacturers' recommendations.
- The team investigated a large housing complex of condominium buildings in the Burnt Stores area. These buildings appeared to perform well, with very few tiles damaged or missing. But there was evidence of tiles with adhesive deposits of improper size and location, as outlined in adhesive manufacturers' guidelines.

4. Hip and Ridge Attachment. Teams were able to inspect the attachment of hip and ridge tiles. In general, the method commonly used was placement of trim tiles in beads of mortar along the two sides of the trim tiles. The field investigation indicated that this attachment method resulted in major damage on many structures. In numerous cases where no other apparent tile damage was present, hip tiles became dislodged and scattered across the field of the roof, damaging additional tiles. Teams found evidence of lack of mortar and lack of bonding to tile. In many cases, hips that were still in place had trim tiles that were loose to the touch. In these installations, there did not appear to be any additional forms of attachment beyond the beads/strips of mortar. The mortar appeared to be job-mixed (mixed at the site by the contractor).

INDIVIDUAL ROOF REPORTS

1.01 Starboard Point #3, 1250 W. Marion, Punta Gorda

TYPE OF STRUCTURE—Multi-family home

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, flat

ROOF HEIGHT—40 ft.

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Building sustained about 30% roof damage, with 10% tile blow-off. Ridge and hip tiles were installed in mortar beads. A significant portion of hip tiles were dislodged, exhibiting visible damage to field tiles in adjacent areas. Some pull-out of fasteners from substrate was observed.

COMMENTS—This 40 ft. high condo complex was built in 1999. The tiles were installed direct to the decks with one screw (2-7/16 in. long) per tile. The building was adjacent to inlet water areas near Punta Gorda Isle Bridge and received wind impact from both directions as the storm traveled through.

1.02 Starboard Point #2, 1250 W. Marion, Punta Gorda

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, flat

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—This roof had about 25% of the roof tiles damaged, with about 10% tile blow-off. There was some cascaded tile breakage along hips and dormers. This was from hip tiles that failed because of mortar application. This building experienced internal pressurization via gable vents that allowed air to enter and blow out sections of the overhanging soffit.

COMMENTS—This building, having the same configuration as the previous one, also experienced storm winds from both directions. The flat concrete tiles were installed to the deck with one screw (2-7/16 in. long) per tile.

1.03 Starboard Point #1, 1250 W. Marion, Punta Gorda

TYPE OF STRUCTURE—Multi-family home

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, flat

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Approximately 25% of the roof tiles were damaged, with about 10% tile blow-off. There was some cascaded tile breakage along hips and dormers. This was from hip tiles that failed because of mortar application. This building also experienced internal pressurization via gable vents that allowed air to enter and blow out sections of the overhanging soffit. Most damaged tiles were adjacent to hips that blew off.

COMMENTS—This building was similar to 1.01 and 1.02 and was built in 1998. The flat concrete tiles were installed direct to deck with one screw (2-7/16 in. long) per tile.

1.04 Breakers Court #2, W. Marion Street, Punta Gorda

TYPE OF STRUCTURE—Multi-family home

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile

ROOF HEIGHT—40 ft.

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—This building had about 30–35% damaged tile, with a significant amount of loose tile found scattered across the field of the roof. Partial dry-in had been performed, so tiles from the east side had been moved to the west side for disposal. Significant damage was noted to parking garage roof tiles directly below the west side of the building. Tiles from the upper roof had landed on the carport. Since the roof was in a partial dry-in with new underlayment tacked down, the team was not able to determine when the tiles had fallen on the lower roof. Construction crews used a front-end loader to pick up tiles on the ground. On viewing the mortar application, it was noted that mortar paddies were applied in improper areas under the tile and had not made contact with the tile in most cases. Hip and ridge tiles were set in beads of mortar and were loose.

COMMENTS—This 40 ft. high condominium building was built in 1995. Roof tiles were installed in a mortar-set application.

1.05 Breakers Court Building #1, W. Marion Street, Punta Gorda

TYPE OF STRUCTURE—Multi-family home

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—As with 1.03, the roof sustained about 28% damage, with a significant amount of loose tile scattered across the roof surface. Hip tiles that were mortared were loose, and broken tiles were noted in adjacent areas of the field of the roof. The team identified tiles that were in place but not bonded to the mortar, below. Evidence indicated that some tile had been in contact with mortar, but had lost adhesion.

COMMENTS—This building was constructed similarly to 1.03. Tiles were installed with the mortar-set system.

1.06 129 Breakers Court, W. Marion Street, Punta Gorda

TYPE OF STRUCTURE—Multi-family home built in 2003

EXPOSURE—C (Located less than 400 ft. south of the Peace River.)

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile—medium profile

ROOF HEIGHT—40 ft.

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—This roof performed very well. Approximately 5% of the tiles were damaged. Most of the damage was adjacent to mortared hip tiles that were loose.

COMMENTS—This 40 ft. high building was a condominium complex built around 1995. The roof was installed with a concrete medium-profile tile with one 2-7/16 in. screw per tile.

1.07 129 Breakers Court Building #2, W. Marion Street, Punta Gorda

TYPE OF STRUCTURE—Multi-family home built in 2003

EXPOSURE—C (Located less than 400 ft. south of the Peace River.)

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, flat

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—This building sustained approximately 80% roof damage with a significant number of tiles scattered across the roof surface. Close examination of the foam adhesive indicated that the foam paddies were improperly placed under tiles and were of insufficient quantity to make proper contact with the tiles. A significant number of tiles showed no evidence of making contact with the adhesive. In one roof area, the adhesive was placed as a continuous bead instead of a paddy as required by the adhesive manufacturer.

COMMENTS—This building was constructed similarly to 1.06. Tiles were installed using one-component adhesive foam.

1.08 123 Maria Court, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 2002

EXPOSURE—C (This house is within 1,000 ft. of the Peace River; it is also in a canal area.)

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, flat

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—The roof sustained minor damage from wind-borne debris. Approximately 15 ft. of eave metal and fascia board were damaged along the front of the house. A complete 16×20 ft. patio canopy was blown from a neighbor's house and came to rest in the front yard; it had traveled over the top of a house and across a cul-de-sac, approximately 100 yards. A power pole and transformer were also strewn across the front yard. The house sustained about 5% tile damage in those areas where construction materials impacted the roof.

COMMENTS—Tiles on this roof were installed with two-component foam adhesives. Tiles were installed with the single-paddy configuration for the field tile but with two paddies per tile on the eave course of tile.

1.09 111 Maria Court, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1999

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, medium profile

ROOF SLOPE—7″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—The roof sustained very minor damage, estimated at 5%. Tile damage was confined to the field tiles adjacent to mortared hip tiles that broke loose.

COMMENTS—Tiles were fastened with one screw (2-7/16 in.) per tile on battens. Hip tiles were installed in mortar beads.

1.10 111 Donna Court, Punta Gorda

TYPE OF STRUCTURE—Single story family home built in 2002

EXPOSURE—C (Within 800 ft. of the Peace River and located at the intersection of two canals)

WALL CONSTRUCTION—Masonry

ROOF TYPE—Clay tile, medium profile

ROOF SLOPE—7″:12″

ROOF DECK—Solid deck

WIND SPEED—140–150 mph

NOTED DAMAGE—The roof had minor damage—less than 5%. Damage was due to 2 in. thick sprayed polyurethane foam (SPF) roofing material that impacted the roof from two houses away. The SPF roof was 90% gone, and foam debris was scattered on all each side of the house.

COMMENTS—Tiles were fastened with one screw (2-7/16 in.) per tile, installed on wood battens.

1.11 3410 and 3317 Sunset Key Circle, residential area, Burnt Stores

TYPE OF STRUCTURE—Single family home and multi-family home

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF TYPE—Clay tile, high-profile

ROOF SLOPE—7″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—The field tiles appeared to remain intact on all of the buildings. We did find evidence of hip and ridge tiles that were installed with just mortar being dislodged and broken.

COMMENTS—This complex area was located on the harbor entrance of the Marina in Burnt Stores. It consisted of four 8-story condominium buildings with approximately 100 homes. Teams investigated three of the 2-story homes (1.11) and one of the high-rise complexes (1.11A). Tiles were installed directly to the deck with large single paddies of two-component adhesive foam.

1.12 Redfish Cove, Burnt Stores—Subdivision of homes

TYPE OF STRUCTURE—Single family homes (40)

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

COMMENTS—Most tile installations performed well. We were able to locate three homes where field tiles apparently blew off. Further investigation of those particular roofs showed evidence that mortar paddies were too small, and placed too low on the roof. It was also noted that some structures had lost small portions of the hip tiles that had been mortared in place.

1.13 Redfish Cove, Burnt Stores area

TYPE OF STRUCTURE—Single family home (multiple)

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile

ROOF HEIGHT—90 ft.

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Observed damage included tiles missing from some roof turrets—approximately 15–20% tile loss. The only other noted damage consisted of trim displaced from hip sections.

COMMENTS—The team inspected the high-rise complex, estimated to be 90 ft. tall, that had a series of steep pitched dormers located across the roof. While some roof turrets suffered tile loss, mainly on their windward sides, other turrets and the high-rise roof appeared to perform well. The team investigated the Redfish Cove subdivision, which had approximately 90 homes. Tiles were attached using a single large paddy of two-component adhesive per tile. The team did not find any evidence of tile failure, other than at the turrets mentioned above.

1.14 25188 E. Marion Ave., Emerald Point, Punta Gorda

TYPE OF STRUCTURES—40 single family homes and four 4-story condos, built around 1978/1979

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPES—

1. Concrete tile, medium profile (single family homes)
2. Dimensional asphalt shingles (three condos)
3. Standing seam metal (two buildings)

ROOF SLOPE—5″:12″ (tile roofs)

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—In the single-family homes, there was evidence of partial trim loss at hips that were mortared in place. The asphalt shingled roofs suffered severe blow-off displacement (approximately 80%), with subsequent loss of underlayment and sheathing. There was no visible damage to concrete tiles or standing seam roofs.

COMMENTS—Tiles on the single story homes were installed using a two-component adhesive system with a single large paddy configuration. The 4-story complexes had mansard roofs with various coverings. Concrete tiles on the single story homes were attached using one screw per tile.

1.15 1500 Appian, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1974

EXPOSURE—B. The house sits on a three-street corner with open exposures created by the streets in the north, east, and south directions. It also sits at the end of a canal that creates another open exposure to the northwest. The house is located less than 4,000 ft. south of the Peace River.

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, low profile

ROOF SLOPE—4–6″:12″ (all hip roof design)

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Wind damage was approximately 10% on perimeters.

DAMAGE INITIATION AND PROPAGATION—Tiles on the eave courses were lifted because of inadequate attachment. The foam was attached near the top of each tile. The foam adhesive failed by detaching from both the underlayment system and the roof tile, but particularly from the underlayment.

COMMENTS—Tiles were attached using single-component foam adhesive. The eave course was not attached per manufacturer recommendations. Exact roof age was not determined but appeared to be less than 5 years old. The garage door was breached and pushed to the inside. The homeowner stated that when the garage door was partially blown in, the side window of the garage was blown out. This quickly depressurized the garage, and no structural damage to the house was observed.

1.16 1135 La Palma Court, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1980

EXPOSURE—B. The house is located at the end of a cul-de-sac and at the intersection of two canals. It is exposed to the water on the west and south directions and somewhat protected on the east and north directions by other homes. The house is within 500 ft. of an open area, with a large lake to the east. The mangrove-harbor interface is about 3,000 ft. to the west.

WALL CONSTRUCTION—Masonry

ROOF HEIGHT—17 ft.

ROOF TYPE—Concrete tile—flat (All hip roof design)

ROOF SLOPE—4″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Approximately 10% damage to perimeter areas

DAMAGE INITIATION AND PROPAGATION—Hip and ridge trim tiles became dislodged and impacted field tile.

COMMENTS—This roof was 3 years old. Tile was attached with one screw per tile through one of the pre-formed holes at the top of the tile. At the eave, there was also evidence of a bead of foam adhesive applied between the underlayment system and the tile. The bead of foam adhesive was placed so it attached about 2 in. below the top of the first two tile courses from the eave. No ridge boards were used at ridges. A specially shaped tile (a truncated V) was used at hips and main ridges and connected to the tile roof with a thin bead of mortar.

1.17 879 Napoli, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1972

EXPOSURE—B. This house is located on a canal to the northwest and on a street corner to the southeast. The streets create an open exposure to the east and south of the house.

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, low profile

ROOF SLOPE—6″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Approximately 30% of tiles displaced at perimeter areas and roof field. Both mortar-to-underlayment and mortar-to-tile separation failure was observed, but most failures consisted of separation of mortar from tile.

DAMAGE INITIATION AND PROPAGATION—Tiles became dislodged from mortar paddies because of both an insufficient amount of mortar and incorrect placement.

COMMENTS—Mortar-set tile installation was used. The tile roof age was not determined. Mortar paddies averaged 7–9 in. in diameter, with one paddy per tile. No ridge board was used at the hip and main roof ridge.

1.18 859 Napoli, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1989

EXPOSURE—B. The house is on a canal, which is to the west. The house is centrally located in Punta Gorda Isles and at least 3,500 ft. from open water.

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, medium profile

ROOF SLOPE—4–6″:12″ (main roof gable end design)

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Approximately 25% damage to field tile in perimeter areas, and around hips and ridges

DAMAGE INITIATION AND PROPAGATION—Tiles were fastened with single 8D nails on battens, which pre-dates the current fastening requirements. The relatively weak holding power of this method appears to be directly related to its failure to secure tiles.

COMMENTS—Roof age is not known. The east-facing garage door was breached inward, but no structural damage occurred. Some broken tiles were displaced onto the west slope of the roof. These details seem to indicate the strongest winds came from the east.

1.19 2500 Rio Tiber Drive, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1985

EXPOSURE—B. The house is located in a canal area with limited exposure to a canal to the west. It is located within 1,500 ft. of an open area with a large lake to the east and within 3,000 ft. of the harbor-mangrove interface.

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile

ROOF SLOPE—6″:12″ (multi-hip roof shape)

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Approximately 10% damage on one roof section

DAMAGE INITIATION AND PROPAGATION—Single-component foam paddies (one per tile) did not make adequate contact with field tiles and lacked the necessary tile-to-tile contact, as well. Eave course was similarly attached. Typical foam adhesive paddy size was approximately 3 in. in diameter.

COMMENTS—Age of tile roof is unknown.

1.20 1601 Montia Court, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1970

EXPOSURE—B. This house is located at the intersection of two canals, so the terrain is open for about 200 ft. on the east and south sides. Open area extends several hundred feet in the southeast direction. The house is somewhat protected on the west and north sides by other houses. It is located about 2,000 ft. south of the Peace River.

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, flat

ROOF SLOPE—6″:12″ (All hip roof shape)

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—None

COMMENTS—Recent re-roof utilized a single-component adhesive, two paddies per tile system.

1.21 2221 Mauritania Rd., Deep Creek

TYPE OF STRUCTURE—Single family home built in 1988

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF TYPE—Asphalt dimensional composition shingle

ROOF SLOPE—4″:12″ (All hip roof design)

ROOF DECK—Plywood

WIND SPEED—130–140 mph

NOTED DAMAGE—30% of shingles were displaced

DAMAGE INITIATION AND PROPAGATION—Primary mode of failure was fastener pull-over with limited examples of pull-out.

COMMENTS—Owner claimed that the roof was 5 years old.

1.22 115 Breakers Court, Punta Gorda

TYPE OF STRUCTURE—Single family home. The Peace River is located less than 100 ft. to the north.

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile

ROOF SLOPE—4–8″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—80%

DAMAGE INITIATION AND PROPAGATION—Tiles separated from mortar paddies (at 4″:12″ slope area) where mortar paddies were undersized and improperly placed. Tiles pulled over nails (8″: 12″ slope area) where tiles were nailed to battens with two smooth-shanked nails per tile.

COMMENTS—Roofs were installed during middle-to-late 1991, prior to current code requirements.

1.23 1602 Montia Court, Punta Gorda

TYPE OF STRUCTURE—Single family home built in 1970

EXPOSURE—B. The house is located at the end of a cul-de-sac. It is also located at the intersection of three canals with open exposures to the east, north and northwest. The house is located about 2,000 ft. south of the Peace River.

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, flat

ROOF SLOPE—4″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—Approximately 12–15% damage to eaves and ridge areas

DAMAGE INITIATION AND PROPAGATION—Undersized mortar paddies and improper placement appeared to be the cause.

1.24 24500 Airport Rd., Punta Gorda

TYPE OF STRUCTURE—Multi-family homes (eight) built in 1990

EXPOSURE—B. There are two large lakes located to the east of the complex. This complex consists of multi-family homes and an office building, all surrounding a small lake.

WALL CONSTRUCTION—Masonry

ROOF TYPE—3-tab asphalt shingles

ROOF SLOPE—4″:12″ (main roof is a gable end design)

ROOF DECK—Oriented strand board

WIND SPEED—140–150 mph

NOTED DAMAGE—90% blow-off

DAMAGE INITIATION AND PROPAGATION—Some sheathing blew off (2–3%). Most shingle displacement was due to pull-over.

1.25 Deep Creek Elementary School

TYPE OF STRUCTURE—Institutional

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF TYPE—Dimensional asphalt shingle

ROOF SLOPE—5″:12″

ROOF DECK—Mineral board/metal deck

WIND SPEED—130–140 mph

NOTED DAMAGE—Structural failure (some areas); minor damage (other areas)

DAMAGE INITIATION AND PROPAGATION—Expandable roofing fasteners used to attach shingles to mineral board failed to secure shingles properly.

1.26 2210 Taylor St., Punta Gorda

TYPE OF STRUCTURE—Multi-family home

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile, medium profile

ROOF SLOPE—5″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

NOTED DAMAGE—80% tile blow-off, all areas

DAMAGE INITIATION AND PROPAGATION—Approximately 15% of the roof sheathing blew off. The remainder of the roof exhibited blow-off of underlayment as a result of too few fasteners.

COMMENTS—Mortar paddies were undersized.

1.27 Sun Trust Strip Mall, Rio De Janiero, Deep Creek

TYPE OF STRUCTURE—Commercial

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF TYPE—Concrete tile—“S” type

ROOF SLOPE—6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

NOTED DAMAGE—Approximately 8% of tiles were displaced by wind

DAMAGE INITIATION AND PROPAGATION—Tiles blew off sporadically because of nail pull-out of battens. Tiles were attached with a single 6D nail in the pan section of each tile.

1.28 Punta Gorda Isles drive-through

The team spent a portion of the day driving the streets of the local community. While most of the buildings in the area sustained major structural damage, the team attempted to locate homes in the peripheral areas where some form of roofing material was available. The team was able to find very few homes that did not have significant blow-off of not only roofing materials but also substantial portions of substrate materials. Wind speeds were estimated at 140–150 mph.

COMMENTS: Punta Gorda Isles appears to have been in the path of the strongest storm winds experienced inland during Hurricane Charley (refer to Appendices B and C). The terrain around the area was open water on the north, west, and south sides. Much of the area was constructed with canals connecting to most residential properties. Foliage consisted primarily of sparsely-spaced palm trees. Observations indicated that older 3-tab shingles did not survive, and they were present in debris piles. Because of the high wind speeds and massive storm-related debris, which blocked many streets, the team was not able to properly assess most roofs. Most of this area was older houses, with few new homes to assess.

1.29 Harbor Heights area of Port Charlotte

Maps of estimated maximum wind speeds seem to indicate Harbor Heights experienced among the highest winds to hit the inland areas during Hurricane Charley (refer to Appendix C). Much of the terrain in this area consists of open, vacant lots with few trees. Wind speeds were estimated at 130–140 mph.

Teams performed cursory “drive-by” appraisals of various roofing materials as outlined by the RICOWI Executive Committee. Team members traveled north on Highway 41, then east and west of the highway to visit areas along the outer perimeters of the severe wind zones. Primary focus was on finding areas that had less structural damage to concentrate more on roofing material performance and failure. Using a spreadsheet, data were assembled on addresses, roof types, and indicated damage. The following charts provide information assembled from the 227 homes logged from team 1 and the 76 homes logged from team 1A.

As part of the summary tables, the team attempted to evaluate the roof damage of the various structures according to the categories of None, Minor, Partial, and Major. Care was taken to ensure that similar ratings were made for all structures surveyed. The full team agreed on the damage status of each roof.

Table 1 shows the results for the streets viewed on the West Harbor and East Harbor sides side of Highway 41.

Table 1. Harbor Heights Area of Port Charlotte—west and east

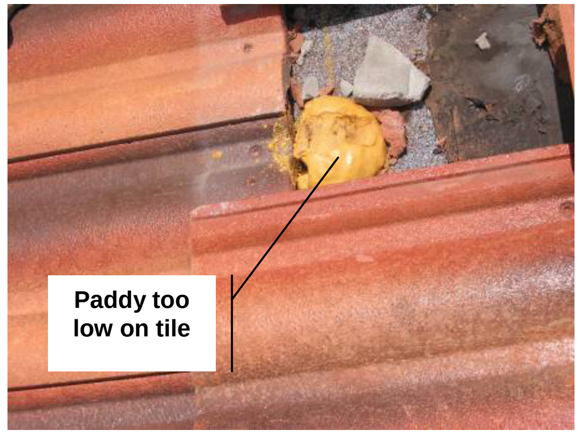
Quick street surveys

Description	None	Minor	Partial	Major	Total	Wind speed
Harbor Heights West Area of Port Charlotte						130–140
3-tab	9	31	25	48	113	
Dimensional	49	13	12	11	85	
Metal-through fastened	1	1	0	2	4	
Built-up flat	2	8	2	29	41	
Tile—mortar set	0	3	6	2	11	
Tile—mechanical fastener	1	5	2	0	8	
Tile—adhesive set	0	0	1	0	1	
Harbor Heights East Area of Port Charlotte						130–140
3-tab	1	3	1	10	15	
Dimensional	11	16	9	9	45	
Metal-through fastened	0	0	0	0	0	
Built-up flat	0	0	0	0	0	
Tile—mortar set	1	4	4	1	10	
Tile—mechanical fastener	0	1	0	1	2	
Tile—adhesive set	3	0	1	1	5	
Total Roofs					**340**	

PHOTOGRAPHS OF ROOF DAMAGE

The following photographs are provided as a brief summary of the types of roofs that were viewed during this field investigation. Because of space limitations, we could not include all of the photos taken.

1-04-1. Residence in Punta Gorda Isles. Mortar failures found included loss of bonding of mortar-to-substrate-to tile, or in this case, underlayment broken apart. There are currently no test requirements for underlayments that address the bonding capabilities for use as a “bondable” underlayment for roofing material. Photo shows tile mortar and underlayment.



1-11-1. Burnt Stores Marina. Adhesive system with a paddy that is too small and in the wrong location.

1-11-2. Burnt Stores Marina. Foam adhesive-set system with good results.

1-13-1. Punta Gorda Isles. Four-story high-rise, hip and ridge tile damage.

1-19-1. Punta Gorda Isles. Adhesive system with paddies that are too small and improperly located.

1-21-1. Harbor Heights. Fasteners here are 10 in. o.c. rather than six per shingle, as required by code.

1-21-6. Harbor Heights, Port Charlotte. This photo shows the magnitude of structural damage that occurred during Hurricane Charley. Note amount of debris that was present.

1-22-1. Punta Gorda Isles. Mortar-set system tile failure. An estimated 60% of tiles were dislodged.

1-29-1. Harbor Heights–East. Area of lower wind impact. Photo shows shingle loss.

1-29-2. Harbor Heights. Note fastener spacing in this lower wind speed area.

1-29-3. Harbor Heights area. The 3-tab shingles were blown off this roof. Insulation from the attic is visible, along with base sheet and wood sheathing board substrate.

1-29-4. Punta Gorda. This photo shows through-fastened metal roof panels with fasteners 6 in. o.c. up seams. Some oil canning of metal panels was noted.

1-29-5. Stone-coated metal roofing. Metal tiles rotated on batten as a result of high winds.

Debris

As a final observation, the team wishes to stress the level of debris that was present from Hurricane Charley. As the strongest storm with the greatest damage, it should be noted that it left significant debris in the damage path. This included vegetation, utilities, household items, personal effects, and building materials. There was no specific category that struck the teams as being predominant.

However, while some structural failure due to internal pressurization was observed, it was rare on residential site-built structures, even in areas of the most severe damage. In Punta Gorda Isles, for example, a few breaches of the building envelope were observed. Many of these involved garage doors that were blown in or out. In a handful of these cases, it was found that another window or door had failed inside the garage. This sequence of failure may have prevented structural damage.

Another type of failure noted was roof deck attachment failure at gable ends or at eaves with soffits. While structural failures were isolated and few, this appeared to be one of the more common types of structural failure.

Debris fields—Harbor Heights and downtown Punta Gorda

HURRICANE CHARLEY: TEAM 4

OVERVIEW

Team 4 members investigated a variety of steep slope roofs. The team visited residential areas affected by Hurricane Charley that were in relatively close proximity to Punta Gorda and Charlotte Harbor/Port Charlotte, Florida. Specifically, the team visited homes in communities known as Burnt Stores, Pirate Harbor, Rotunda, Boca Grande, Sanibel Island, and Port Charlotte. Primary focus was given to areas hit by the highest wind speeds and to surveying areas with a diversity of roofing materials. There was a basic belief, from the start, that some areas were exposed to winds exceeding those listed in the Building Code. Therefore, it was expected that areas farther away from the center of the storm would have been exposed to lower wind speeds. The goal was to investigate the performance of different roofing materials exposed to winds of varying severity. The team was interested in observing roofs located in a cross section of the total hurricane impact area.

The team surveyed a total of 34 roofs, consisting of 10 through-fastened, 14 composition shingle, three tile, four metal shingle, and three wood shake roofs. We additionally did cursory surveys on eight streets to gain a larger perspective of the hurricane's overall impact. These "street surveys" classified roofs in four damage categories: "none," "minor," "partial," and "major" based on observations made while driving through those neighborhoods.

Team Members

Each of the following members participated on Team 4 for at least one of the four investigation days:

Joe Wilson, Report Writer
Bas Baskaran, Sample Collector
Jeff Burton, Data Recorder
Peter Croft, Photographer
Hare Boxall, Observer
Bill Young, Observer
Brent Woody, Sample Collector
Lonnie Ryder, Observer
Chris Nery, Observer

Summary Observations

It was noted that different construction methods were employed on two different barrier islands, Boca Grande and Sanibel. Although it is assumed that Sanibel was exposed to higher winds (south of the hurricane's eye) than Boca Grande, Boca Grande construction practices were more resistant to hurricane winds than were Sanibel practices.

Evidence of roof failure from wind-borne debris was noted. The debris was found, in some cases, to breach or adversely affect the performance of the building envelope. Among the many roofs damaged to some degree by the hurricane winds, there were many cases where the roofing systems were left undamaged.

Comments on modes of roofing failure observed by Charley Team 4 are included with the report for Ivan Team 3 because of the similarity of findings.

Observed Damage Modes

Insufficient Attachment. Insufficient fastener attachment was commonly observed in both the type and the number of fasteners used. Cases were observed where the fastener type selected was not adequate, in conjunction with the frequency of placement, to resist the wind forces. Examples of roof failure occurred where fasteners were used that would not have been normally specified for a particular application. It was found that the fastening requirements specified in a later version of the building code were an improvement over those of the earlier code. Fastener inadequacy was also prevalent in the attachment of substrates and framing members.

Workmanship. The team observed instances where the construction of the roof compromised its performance against the hurricane-force winds. Cases were found of missing or misplaced fasteners. Other cases were found where the construction of the building's roof structure was not according to code or standard practice.

Improper Material Selection. Examples were found of roofs where either one component or a combination of components failed to withstand the force of winds. The failure of one component on the roof or used as part of the roof structure was found to influence the performance of other materials. Roofs that were exposed to and survived the hurricane winds were supported by an entire system having the required materials installed according to specification.

Structural Failure. Cases were observed in which the structural integrity of the building was breached and the roof failed.

Age and Maintenance. In some cases in which similar material types were used, newer roofs performed better in the hurricanes than did older materials. Some of the performance differences between older and newer materials can be attributed to better-specified application methods, but in similar roofs with equivalent application methods, it was observed that newer roofs fared better than older ones. Examples were found in which the performance of the roof was weakened by corrosion or deterioration of components.

Winds in Excess of Design. In some instances the roof system failed even though it was constructed according to an appropriate updated specification. These examples were found for both the roof system and the building's structure.

INDIVIDUAL ROOF REPORTS

4.01 24176 Yacht Club, Pirate Harbor

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

WALL CONSTRUCTION—Wood framing

ROOF TYPE—Through-fastened metal

SLOPE—3–4″:12″

ROOF DECK—Plywood

WIND SPEED—140–150 mph

METHOD OF ATTACHMENT—Screws, six per square foot

NOTED DAMAGE—Minimal. Lost 20% of vinyl siding, and all of soffits. Minor damage from wind-borne tile from an adjacent roof.

SITE COORDINATES—N 26' 48 336, W 82' 02 925

4.02 24261 Captain Del Rio Blvd. Charlotte Harbor

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

WALL CONSTRUCTION—N/A

ROOF TYPE—Composition shingles

SLOPE—6″:12″>

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Roofing nails, six per shingle

NOTED DAMAGE—Minor damage to hip and ridge sections. Hip pieces were lifted up and torn off on 25% of hip sections. No field loss.

SITE COORDINATES—N 26 48 281, W 82 02 774

4.03 24271 Captain Del Rio Blvd. Charlotte Harbor

TYPE OF STRUCTURE—Single family home

ROOF TYPE—3-tab asphalt shingles

EXPOSURE—B

WALL CONSTRUCTION—Concrete masonry unit (CMU)

SLOPE—3–4″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Staples, four to five per shingle

NOTED DAMAGE—70% of roof damaged. Twelve-year-old single layer of shingles loosened. Wrong angle of staple for shingle attachment. Shingles torn loose from staples.

4.04 24251 Pirate Harbor, Charlotte Harbor

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

WALL CONSTRUCTION—Concrete block

ROOF TYPE—Composition shingles

SLOPE—3–4″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Roofing nails, six per shingle

NOTED DAMAGE—5 to 10% of roof damaged. Shingle failure on rear section of house. Nails placed in seal strip. Damaged shingles were ripped loose.

4.05 24156 Yacht Club Blvd. Pirate Cove, Charlotte Harbor

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—N/A

ROOF TYPE—“S” concrete tiles

SLOPE—4–6″:12”

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Cement mortar

NOTED DAMAGE—50% of roof damaged. Field damage occurred as a result of ridge and hip tiles coming loose from cement attachment and hitting/breaking other tiles. Hips and ridge pieces were lost all around the house. Field tiles were mostly in place, but some field tiles came loose from cement attachment patties.

SITE COORDINATES—N 26 59 813,W 82 02 958

4.06 24166 Yacht Club Blvd. Pirate Cove, Charlotte Harbor

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

ROOF TYPE—Flat concrete tiles

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—2-in.-long nails, zero to one per tile

NOTED DAMAGE—80% of roof damaged. Soffits were lost on 50% of home. Damage occurred at two corners of home where sheathing and edging were lost. Building had 150-mph shutters that failed because of fastener shear. One nail per tile, or less, was attachment method.

4.07 128 Carrick Bend Road, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Standing seam metal

SLOPE—6″:12″ >

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Nails

NOTED DAMAGE—None

4.08 350 Gulf Blvd., Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—N/A

ROOF TYPE—Aluminum shingles

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—2-in. ring shank nails, six per 48-in. panel

NOTED DAMAGE—50% of roof damaged. Aluminum shingles that clip/lock at the front to rear of lower panel lifted off roof. Some shingles pulled aluminum ring shank nails out, and others tore from nails. Some shingles disengaged at the front lock points, with the rear of the panels still attached by nails.

SITE COORDINATES—N 26 44 272,W 02 15 777

4.09 Pink Elephant Restaurant, Bayou Street, Boca Grande

TYPE OF STRUCTURE—Single story restaurant

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Aluminum shingles

SLOPE—3–4″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—2-in. ring shank nails, six per 48 in. panel

NOTED DAMAGE—Entire roof damaged. Many roof panels disengaged at the front from the rear-locking panel below. Panels attached with six nails; many were located too close to the rear edge and ripped out.

4.10 Gasparilla Island Tennis 2 Club, Bayou Street, Boca Grande

TYPE OF STRUCTURE—Single story storage building

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Steel granular coated shingles

SLOPE—4–6″:12″

ROOF DECK—Installed over existing wood shake roof

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—12D ring shank nails, five per 48 in. panel

NOTED DAMAGE—No roof damage and no structural damage. (Note: This tennis club structure is similar to the following structure (4.11), which was heavily damaged.)

4.11 Gasparilla Island Tennis Club, 5th and Bayou Street, Boca Grande

TYPE OF STRUCTURE—Single story club building

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Steel granular coated shingles

ROOF PITCH—4–6″:12″

ROOF DECK—Installed over existing wood shake roof

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—12D ring shank nails, five per 48 in. panel

NOTED DAMAGE—Roof was completely lost. Granular coated steel roof installed over wood shake with 1×4 and 2×2 batten system. The 2×2 battens pulled loose from 1×4 battens. The entire roof blew off with 2×2s still attached to panels. One end of the gable roof blew out, removing 8 linear ft. of plywood and an entire gable end. Structural damage occurred at the gable end, and the roof unzipped beginning from the damaged gable end. Shake roofs in close proximity to this roof were undamaged.

SITE COORDINATES—N 26 45 123, W 82 15 797

4.12 9630 Arsipe Circle, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Roofing nails, six per shingle

NOTED DAMAGE—Very limited damage at hips and ridges. Hip and ridge damage. Some soffit damage was evident.

4.13 9606 Arsipe Circle, Boca Grande

TYPE OF STRUCTURE—Single family home (relatively new)

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Roofing nails, six per shingle

NOTED DAMAGE—30% of the field was damaged. Very minor ridge damage. Significant field damage from nails placed in seal strip. Damage to neighboring houses ranged from none to minor damage. Screened patio (lanai) was intact.

SITE COORDINATES—N 26 57 094, W 82 11 734

4.14 9590 Arsipe Circle, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—6″:12″ >

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Roofing nails, six per shingle

NOTED DAMAGE—Minor damage at hip/ridge line. Approximately 60 hip and ridge shingles were lost. Some minor soffit damage occurred. Ridge shingles tore loose from nails.

4.15 124 and 126 Carrick Bend Road, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—6″:12″ >

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Roofing nails, four to six per shingle

NOTED DAMAGE—Damage was limited to field and hips on one side of house. Damage was caused primarily by inconsistent nailing. Some shingles were attached with four nails and some with six. Some shingles were nailed in seal strip.

4.16 10527 Aztec Road, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Staples

NOTED DAMAGE—70% of roof damaged. Shingles blew off around entire roof. Staples placed in seal strip. Similar roof adjacent to this home was undamaged.

SITE COORDINATES—N 26 52 406, W 82 11 513

4.17 122 Carrick Bend Road, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—6″:12″ >

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Roofing nails, six per shingle

NOTED DAMAGE—Hip line damage. Three locations (24 in. long) where hip shingles blew off.

SITE COORDINATES—N 26 44 644, W 82 15 758

4.18 16460 Gulf Shore, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Wood shakes (approximately 7 or 8 years old)

SLOPE—6″:12″ >

ROOF DECK—Unknown

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—8D common nails

NOTED DAMAGE—70% damaged. Shake pieces were lost by pulling away from nails. Installation left 14-in. exposure (over-exposed) on hip/ridge shakes. Vinyl siding on adjacent home was entirely blown off.

SITE COORDINATES—N 26 48 096, W 82 16 695

4.19 120 Carrick Bend Road, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Wood shakes

SLOPE—6″:12″ >

ROOF DECK—Unknown

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—8D common nails

NOTED DAMAGE—5–10% of roof damaged. Minor damage to ridge and hip pieces was observed. One small area exhibited shingle loss at rake edge. A small number of shakes were missing in the field of the roof.

SITE COORDINATES—N 26 44 644, W 082 15 758

4.20 574 5th Street, Boca Grande

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—N/A

ROOF TYPE—Concrete “S” tiles

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Nails and cement mortar

NOTED DAMAGE—10% of roof damaged at hip, ridge, and field. Hip and ridge loss with cement mortar all around them. Some field damage caused by impact from hip and ridge pieces. Cement mortared valleys. One nail found per tile.

4.21 1701—1705 Harbor Side Villas, Sanibel Island

TYPE OF STRUCTURE—Multi-family vacation condos

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Architectural metal, galvanized through-fastened crimp

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—¼-in. nails, 12 in. across and 18 in. up

NOTED DAMAGE—50% of roof damaged. Walkway had overhangs with 2×6 in. rafters scabbed 4 ft. inward from wall, cantilevered out. Some 2×6 in. rafters blew off. Some rafters remained but lost sheathing. Roof exhibited substantial red rust, probably due to age. Metal panels tore from fasteners. Oxidation, insufficient number of fasteners, and framing construction led to failure.

SITE COORDINATES—N 23, 32,46, W 82, 11, 832

4.22 Chadwick Square, Sanibel Island

TYPE OF STRUCTURE—Two-story commercial buildings

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Architectural metal

SLOPE—4–6″:12″

ROOF DECK—Plywood and 1×4 in. stringers

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—6D nails, 16 in. across and 12 in. up

NOTED DAMAGE—60% of roof damaged. Some newer panels were replaced. Sheathing was intact. Panels were held to 1×4 in. stringers, but 6D fasteners placed 12 in. o.c. did not hold stringers to plywood.

SITE COORDINATES—N 26 31 408, W 82 11 493

4.23 1681 Royal Palm Drive, Sanibel Island

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Architectural metal

SLOPE—6″:12″

ROOF DECK—Plywood and 1×4 in. stringers

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—4D nails, 12 in. across and 12 in. up

NOTED DAMAGE—80% of roof damaged. 1×4 in. horizontal stringer members attached with 4D nails at 24 in. o.c. Paper was installed over plywood with no apparent effort to nail through to rafters for stringer attachment. Roof panels were attached to stringers with 1¾-in. ring shank roof nails. Stringers attached to plywood released from roof; some pieces were found embedded in adjacent roof.

SITE COORDINATES—N 26 31 408, W 82 11 493

4.24 1550 Angel, Sanibel Island

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Architectural metal

SLOPE—6″:12″

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—Screws, 12 in. o.c.

NOTED DAMAGE—2% of roof damaged. A single panel was lifted from valley.

4.25 1201—1215 Seaside Villas, Sanibel Island

TYPE OF STRUCTURE—Multi-family vacation condos

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Architectural metal

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Clips attached with screws, two screws per clip, clips spaced 18 in. o.c. across, 24–30 in. vertically up roof.

NOTED DAMAGE—20% of roof damaged. Plywood nailed with 6D nails spaced 12 in. o.c., and with staples installed 6 in. o.c. Panels pulled loose from clips, pulling screws out of the plywood (or from the lifting metal panels), which deformed the clips. Some structural damage was seen. Clips also pulled loose from screws.

SITE COORDINATES—N 26 32 959, W 82 11 883

4.26 1532 Angel, Sanibel Island

TYPE OF STRUCTURE—Two-story single family home

EXPOSURE—C

WALL CONSTRUCTION—Block and wood

ROOF TYPE—Composition asphalt shingles

SLOPE—6″:12″

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—Nails, four per shingle

NOTED DAMAGE—20% of roof damaged. Nails were located in seal tab. Tabs were not sealed where nailed. Shingles lifted off, as did a solar panel system (used for pool heating) loosely attached by brackets and straps. Two types of shingles were used; both experienced damage.

SITE COORDINATES—N26 27 941, W82 03 351

4.27 1581 Dixie Beach, San Carlos Bay

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—6″:12″

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—Nails, six per shingle

NOTED DAMAGE—60% of roof damaged. Roof had at least five types of asphalt laminate shingles. Some were nailed, and others were stapled. Some shingles were installed with inadequate exposure. Some shingles had no seal stripping. Shingles appeared to be factory seconds. Several problems were evident, including defective material and installation. Many shingles were torn in half, showing no adhesion of seal tabs (indicating underexposure or no sealant).

SITE COORDINATES—N 26 28 028, W 82 03 176

4.28 1301—1324 South Seas Club, Sanibel Island

TYPE OF STRUCTURE—Multi-family 2-story vacation condos

EXPOSURE—D

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—6″:12″

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—Nails, six per shingle

NOTED DAMAGE—80% of roof damaged. Asphalt shingles pulled loose from nails (six per shingle). Many nails were placed in seal strips. Plywood nailed with some 6D common and staples located 6 in. o.c. Attic pressurized and promoted blow-off of plywood sheets.

SITE COORDINATES—N 26 32 947, W 82 11 815

4.29 974–976 Hilton Vacation Club, Sanibel Island

TYPE OF STRUCTURE—Multi-family 2-story vacation condos

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Wood shakes

SLOPE—4–6″:12″

ROOF DECK—Unknown

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—2-in.-long nails, two per shingle

NOTED DAMAGE—30% of roof damaged. Shingles lifted off back side of house. This was due to shingles pulling loose from nails, nails pulling out, or rusted nails breaking. An adjacent house was stripped of its asphalt shingles.

SITE COORDINATES—N 26 33 058, W82 11 847

4.30 Portofino Restaurant, 23241 Bayside, Port Charlotte

TYPE OF STRUCTURE—Two-story restaurant

EXPOSURE—D

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Through-fastened metal panels, 36 in. wide

SLOPE—3–4″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—1½-in. screws, 12 in. across and 42 in. up

NOTED DAMAGE—20% of roof damaged. Panel attachment was inadequate. Soffit damage was observed. Some pressurization occurred from window blow-out, but was offset by siding blow-outs. Building was adjacent to the bay and very exposed. The 20-year-old asbestos siding remained in place. Much of the vinyl siding became detached.

4.31 Commercial Office Construction Project, US 41, Port Charlotte

TYPE OF STRUCTURE—Single story commercial (very recently installed)

EXPOSURE—C

ROOF TYPE—New 24 gauge standing seam metal (relatively new)

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—Unknown

METHOD OF ATTACHMENT—Two screws per clip, clips spaced 18 in. o.c. across, 32 in. o.c. up

NOTED DAMAGE—50% of roof damaged. No wall damage. Panel deformation was found at lips and seams. In most cases clips were still attached to roof deck, where panels were dislodged. One row of clips was missing from the roof deck.

4.32 Holiday Inn, Punta Gorda

TYPE OF STRUCTURE—Two-story hotel

EXPOSURE—C

ROOF TYPE—Clip-lock standing seam metal (approximately 10–15 years old)

SLOPE—4–6″:12″

ROOF DECK—Cementitious wood fiber decking

WIND SPEED—140–150 mph

METHOD OF ATTACHMENT—1-in.-long screws at 16 in. o.c.

NOTED DAMAGE—70% of roof damaged. Roof panels attached with 1-in. screws at 16 in. o.c. Plywood was attached to decking with screws that did not penetrate through to beams. Plywood pulled loose from decking. Metal panels lost clip securement and pulled through or off plywood, which was also blown off roof. Major structural damage resulted. A significant problem is the apparent failure to securely attach plywood before installing roof panels.

4.33 203 Bayside, Port Charlotte

TYPE OF STRUCTURE—Two-story duplex, two family dwelling

EXPOSURE—C

WALL CONSTRUCTION—Wood frame

ROOF TYPE—Composition asphalt shingles

SLOPE—3–4″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—1¼-in.-long roofing nails, six per shingle

NOTED DAMAGE—100% of roof damaged. Major structural damage, as truss attachment came loose. The ⅝-in.-thick plywood was attached with staples. Bay side (windward direction) was the side with major structural damage. Shingles, plywood, trusses blew off.

4.34 Methodist Church, Seneca and US 41, Charlotte Harbor

TYPE OF STRUCTURE—Two-story church building complex

EXPOSURE—C

ROOF TYPE—Composition asphalt shingles

SLOPE—4–6″:12″

ROOF DECK—Plywood

WIND SPEED—130–140 mph

METHOD OF ATTACHMENT—Staples and 1¼-in.-long roofing nails, four to six per shingle

NOTED DAMAGE—40% of roof damaged (see below).

STRUCTURAL PROBLEMS—(1) Missing cross-bracing on trusses. (2) Plywood stapled 12 in. o.c. with one nail in each corner.

ROOF PROBLEMS—(1) Shingles in sections attached with four staples were all blown off. (2) Shingles in other sections were intact when nailed with six nails. (3) Some hip and ridge loss. Only minor loss of shingles was found in the field of the roof, where shingles were fastened with six nails. A variety of construction methods were observed.

QUICK STREET SURVEYS

Description	None	Minor	Partial	Major	Total	Wind speed
Sunset Pines Circle, Boca Grande, 33921						130–140
Composition shingle	1		1		2	
Concrete tile		3	1		4	
Through-fastened metal	5				5	
Wood shake	1				1	
Standing seam metal	4				4	
San Carlos Bay Dr., Sanibel Island, 33957						100–110
Composition shingle	4	1	1		6	
Concrete tile	1	1			2	
Through-fastened metal	3				3	
Clay tile		1			1	
Gulf View Road, Punta Gorda, 33950						140–150
Concrete tile	16	5	8		29	
Through-fastened metal			1		1	
Composition shingle	1		3		4	
Plum Tree, Punta Gorda, 33955						140–150
Concrete tile		2	1		3	
Composition shingle		1		1	2	
Arsipe Circle, Port Charlotte 33981						130–140
Composition shingle		5	2		7	
Angel Drive, Sanibel Island, 33957						100–110

Composition shingle	1	1	1	2	5	
Through-fastened metal	6	1			7	
Concrete tile	4	3			7	
Wood shake		1			1	
Woodring Road, Sanibel Island, 33957						110–120
Through-fastened metal	7				7	
Composition shingle	3	1			4	
Standing seam	2				2	
Concrete tile		1			1	
North Island Ct., Boca Grande, 33921						130–140
Wood shake	1	1			2	
Concrete tile		2			2	
Standing seam	2				2	
Stone-coated steel “S” panel	1				1	

PHOTOGRAPHS OF ROOF DAMAGE

4-01-4. Undamaged through-fastened metal roof.

4-03-4. Shingles torn loose from staples.

4-05-2. Hip and ridge pieces missing from cement mortar attachment.

4-06-2. Soffit, sheathing, and edge damage along with major roof damage.

4-04-4. Note shingles torn from fasteners.

4-08-3. Aluminum shingles lifted from leading edge metal.

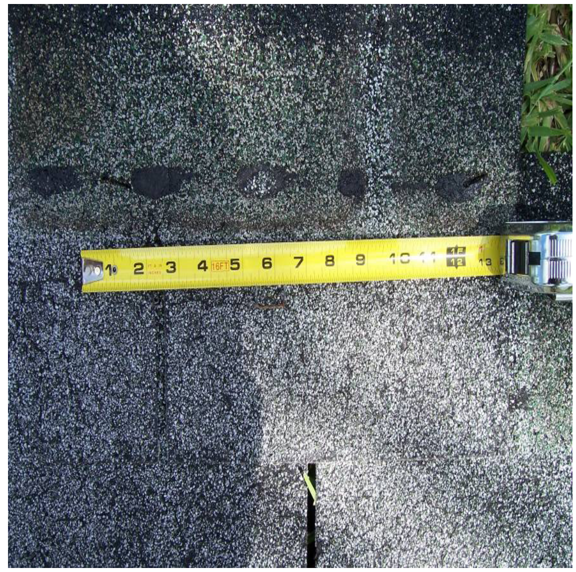
4-10-1. Undamaged granular steel roof on tennis storage building.

4-11-2. Another tennis building, located in close proximity to building in photo 4-10-1, had its granular steel roof blown off as a result of structural damage at gable end.

4-12-2. Minor damage to hip pieces on shingle roof.

4-13-3. Damage to shingles in field of roof located near home pictured in photo 4-12-2.

4-15-4. Major shingle loss as a result of inconsistent nailing (location and/or quantity).



4-16-3, Shingles attached in seal strip prevented adhesion of tabs.

4-17-2. Hip pieces missing on shingle roof.

4-18-3. Hip pieces missing on 7- to 8-year-old wood shake roof.

4-19-2. Raised hip shakes appear to be the result of age and weathering, not strong winds.

4-20-2. Clay hip tiles are missing from cement mortar beds.

4-21-7. Old and rusting through-fastened metal panels have pulled loose from roof.

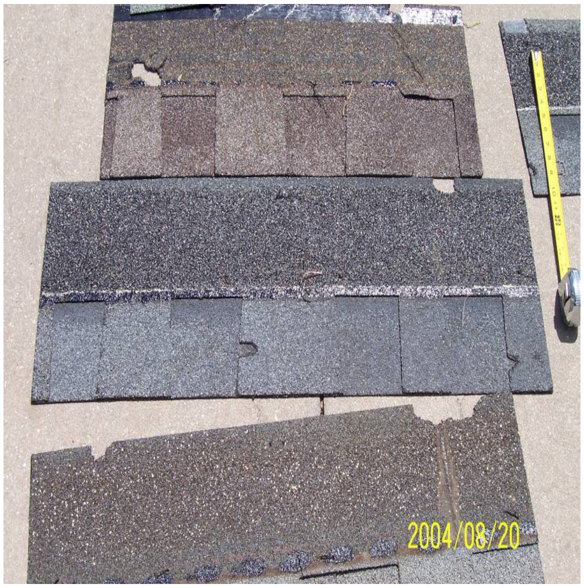
4-21-8. Opposite side of roof shown in photo 4-21-7 with structural and sheathing problems.

4-22-2. Through-fastened metal attached to 1×4-in. stringers blown from roof.

4-24-3. Intact through-fastened metal roof panels missing one valley panel.

4-23-3. Through-fastened metal panels became loose because of 1×4-in. stringers pulling from roof.

4-23-8. 1×4-in. stringers from roof in photo 4-23-3 are impaled in this adjacent shingle roof.



4-27-7. Some of the five types of shingles found on a roof that was damaged.

4-25-6. Standing-seam panels, sheathing, and structure damaged by winds on Sanibel island.

4-28-4. Major damage to asphalt shingle roof on Sanibel Island.

4-28-8. Photo of plywood attachment method from roof in photo 4-28-4 that lost sheathing.

4-29-6. Older wood roof that lost shingles in the field and at hip sections.

4-31-3. Standing-seam panels lifted from irregularly placed clip attachment.

4-32-5. Major roof and decking damage on hotel.

4-32-10. Roof in photo 4-32-5 was attached to decking material pictured in this photo.

4-34-8. Plywood attachment on damaged church.

4-30-2. Most of metal roof still in place on damaged building.

HURRICANE CHARLEY: TEAM 7

OVERVIEW

Team 7 focused its investigations in the Port Charlotte, Punta Gorda, and Boca Grande, Florida area.

Team members

Pete Croft, Report Writer
Hare Boxall, Sample Collector and Photographer
Bart Cox, Photographer
Eric Haefli, Data Recorder

Team Experience

The members had extensive experience with steep slope roofing, which ranged from stone-coated steel panels to concrete barrel and flat tiles. One member (also an architect) represented an insurance company.

Summary Observations

The team investigated ten separate roofs and also conducted street surveys. The reports documented roof construction, wind damage, and likely initiation points of the damage. All ten were steep slope buildings (less than 30 ft. high) in exposures B and C.

Quantity and Type of Roof Materials

These roofs were covered with the following types of roof systems:

- Four asphalt composition shingle roofs from less than 5 to over 25 years old
- Two concrete tile: barrel- and flat-tiled roofs
- Two standing seam systems with 12-in.-wide painted panels
- One through-fastened metal panels with bare finish
- One wood shake roof, “heavy” size

Damage

Observed wind damage ranged from minor (one puncture from wind-borne debris) to extensive (loss of 75% or more of the roof covering). Likely initiation points of damage included lifting of edge metal, loss of hip / ridge caps, and impact damages from wind-borne debris.

INDIVIDUAL ROOF REPORTS

Following are summaries of observations for each roof surveyed. Refer to the photographs at the end of this report for visual documentation. The “year built” was obtained from either the owners themselves or from public records from the Charlotte County Property Appraiser, Murdock Administrative Center, www.ccappraiser.com

7.01 22377 Peachland Blvd., Port Charlotte

TYPE OF STRUCTURE—Single family, one story. Built in 1988

EXPOSURE—B

WALL CONSTRUCTION—Masonry with 60% openings

ROOF SYSTEM—Asphalt composition fiberglass shingle, nailed and stapled

ROOF SLOPE—4–6":12"

ROOF DECK—Plywood decking fastened to “gang-nail” trusses with staples

WIND SPEED—120–130 mph

NOTED DAMAGE—Wind-related damage was severe—up to 75% of roofing. Moderate roof deck failure

DAMAGE INITATION AND PROPAGATION—The most severe winds appeared to come from the southwest and west. While this house was in an Exposure B setting, exposure was generally more open in those directions because of streets and vacant lots.

Drywall was used to protect windows and sliding glass doors on the south elevation of the house inside the pool enclosure. At least one sliding glass door on the south elevation was breached by wind pressure or wind-borne debris, pressurizing the house. The plywood roof deck separated from the roof trusses near and above the opening created by the broken sliding glass door.

Windows were breached on the west elevation. This, along with wind attacking the overhang and infiltrating the eaves, caused the roof deck to be blown upward and off the roof trusses along most of the west elevation. The screened pool enclosure structure on the south side was destroyed. Some of the aluminum structural elements of the pool enclosure were still attached at the eave.

As a result of pressurization of the garage from the west (due to the missing roof deck), the garage door was partially blown out of its opening.

7.02 22365 Peachland Blvd., Port Charlotte

TYPE OF STRUCTURE—Single family, one story. Built in 1994

EXPOSURE—B

WALL CONSTRUCTION—Masonry exterior walls

ROOF SYSTEM—Asphalt composition fiberglass shingle, nailed

ROOF SLOPE—4–6":12"

ROOF DECK—Plywood deck with four nails per shingle

WIND SPEED—120–130 mph

NOTED DAMAGE—Wind-related damage was minor; it was limited to a small area in the field of the roof.

COMMENTS—This home was across the street and west of the home in report 7.01. The owners stayed at home during the storm and said they would not do that again. Debris was flying everywhere. Strongest winds were probably from the southwest and west. Other homes partially blocked winds coming from those directions.

There were no apparent breaches of the building envelope. The screened pool enclosure was intact. Minor-to-moderate membrane damage was noted on the upper half of the south slope.

This nine-year old house (built in 1995) sustained significantly less damage than a home directly across the street, built in 1988. It appears that because this house was more protected by other houses, it experienced less severe wind loads than the older one. This could explain why the only damage was high on the windward side of the roof.

7.03 24123 Peachland Blvd., Port Charlotte

TYPE OF STRUCTURE—One-story strip mall shopping center, built in 1991

EXPOSURE—B. There were some open areas on the north and east sides created by parking lots, and a major four-lane road with a median and open right-of-ways. Some protection is offered on the south side from other commercial buildings.

WALL CONSTRUCTION—Concrete masonry unit (CMU) with stucco finish (according to local sources)

ROOF SYSTEM—Standing seam metal—painted

ROOF SLOPE—3–4":12"

ROOF DECK—Undetermined

WIND SPEED—130–140 mph

NOTED DAMAGE—Wind-related damage was minor and was related to rake edges on gable sections and low slope rolled roofing at the rear of the building. Most store fronts had large glass areas on north and east elevations. There were no apparent breaches of the building envelope. It is unknown if window protection was used.

COMMENTS—The strip mall stores were open for business.

7.04 530 Torrington Street, Port Charlotte

TYPE OF STRUCTURE—One story, single family. Around 1990–1993 (according to local sources).

EXPOSURE—B. This house is located on a corner lot next to a major road with a canal in back. Although it is in a suburban setting, there are partially open exposures in all directions. Strongest winds came from the west.

WALL CONSTRUCTION—Masonry

ROOF SYSTEM—Concrete tile

ROOF SLOPE—4–6":12”

ROOF DECK—Plywood deck

WIND SPEED—130–140 mph

NOTED DAMAGE—Wind-related damage was at the rear. Hips and ridges incurred the initial damage. Soffit damage was also observed.

COMMENTS—Strongest winds appear to have come from the southwest and west. Roof was damaged by wind-borne debris and loosened hip/ridge tiles. Resulting air infiltration caused the building to become pressurized. The west-facing garage door was breached halfway through the storm. The garage was briefly pressurized, then de-pressurized when the glass of the side entry door blew out.

7.05 1401 Tamiami Trail, Port Charlotte

TYPE OF STRUCTURE—One story. Built in 1989 (according to local sources)

EXPOSURE—B

WALL CONSTRUCTION—CMU with wood siding

ROOF SYSTEM—Architectural vertical seam metal roofing with 12-in.-wide pans—painted

ROOF SLOPE—6”:12” (A-frame on large gable building—commercial)

ROOF DECK—Plywood

WIND SPEED—120–130 mph

NOTED DAMAGE—Lower and upper gable edges torn off

DAMAGE INITATION AND PROPAGATION—Roof was damaged by flying concrete tile debris from Punta Gorda Fire Station across the four-lane highway (E to W winds). Many impact spots were noted on the standing seam roof. Gable edge metal appeared to come off, allowing roof panels to be blown back. The metal panel clips spacing was erratic and the clip gauge appeared to be less than the panel itself.

COMMENTS—Building was pressurized when glass in a large A-frame clerestory was broken by wind-borne debris, creating a large opening.

7.06 19179 Aviation, Port Charlotte

TYPE OF STRUCTURE—One-story single family home, built in 1984

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF SYSTEM—Asphalt composition shingles (5 years old) nailed 1–14 in. length

ROOF SLOPE—4–6":12". Primarily gable end shape

ROOF DECK—Plywood

WIND SPEED—130–140 mph

NOTED DAMAGE—75% of roofing was damaged around projections

7.07 19178 Aviation, Port Charlotte

TYPE OF STRUCTURE—One-story single family, built in 1990 (according to local sources)

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF SYSTEM—Asphalt composition shingles—dimensional

ROOF SLOPE—4–6":12". Primarily gable end shape

ROOF DECK—Oriented strand board (OSB)

WIND SPEED—130–140 mph

NOTED DAMAGE—Fastener pull-through occurred over the entire roof. Almost all shingles on the north side were blown off. Minimal roofing damage was observed on the south slope. The homeowner said there was extensive water damage inside.

7.08 19189 Aviation Court, Port Charlotte

TYPE OF STRUCTURE—One-story single family, built in 2002

EXPOSURE—C

WALL CONSTRUCTION—Masonary

ROOF SYSTEM—Concrete tile (hip roof)

ROOF SLOPE—4–6":12"

ROOF DECK—Unknown

WIND SPEED—130–140 mph

NOTED DAMAGE—No visible damage to roof or building

COMMENTS—A lightweight aluminum lanai/pool enclosure survived with only minor screen damage. The pool enclosure frame was diagonally braced.

7.09 19198 Aviation Court, Port Charlotte

TYPE OF STRUCTURE—Two-story, single family, built in 2002 (according to local sources)

EXPOSURE—C

WALL CONSTRUCTION—Wood frame on concrete piles; “high-wind” Wolverine siding with mesh

ROOF SYSTEM—Metal roof, bare finish. Through-fastened panels with screws every 12 in.

ROOF SLOPE—4–6":12". All hip roof shape

ROOF DECK—Unknown

WIND SPEED—130–140 mph

NOTED DAMAGE—No wind-related damage visible from exterior except for extensive soffit damage

COMMENTS—Siding survived with no apparent damage. Most soffit damage was minor, although major soffit damage occurred above the ground-floor open area. Windows had been protected with plywood storm panels.

7.10 Gulf Blvd., Boca Grande

TYPE OF STRUCTURE—Two-story clubhouse, age unknown. Building is much taller than its surroundings and is located close to the water of the Gulf of Mexico.

EXPOSURE—C

WALL CONSTRUCTION—Masonry and wood siding

ROOF SYSTEM—Wood shake (nails used in field, and staples used at hip and ridges)

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—130–140 mph

NOTED DAMAGE—2% roof damage, mainly to hip/ridge loss and at building corners

COMMENTS—Damage was mostly isolated to hip cap blow-off and small field areas (4 ft^2) where shakes blew off.

QUICK ROOF SURVEYS

Following is a summary of “quick roof surveys” performed. They were performed from a vehicle, with one team member making notes of various damage and a photographer taking pictures. About 90% of the sites were NOT viewed from the rear of properties, which, in some cases, was the wind direction. The damage rating system used on these quick roof surveys was as follows:

NO DAMAGE—None visible.

MINOR DAMAGE—Some eave or ridge caps missing, but roof appeared intact.

PARTIAL DAMAGE—A section of the roof edge or field was missing, compromising roof integrity.

MAJOR DAMAGE—Roofing assembly missing, from deck up; whole roof section(s) missing.

7307 Plumtree, Burnt Store Meadows Development, Punta Gorda

TOTAL COUNT—Seven homes viewed

ROOF SYSTEMS—Four concrete tile, three composition shingle

WALL CONSTRUCTION—Masonry stucco

NOTED DAMAGE—Tile—two with minor damage and two partial damage; composition shingle—one with no damage and two with minor damage

CAUSES OF ROOF DAMAGE—Hip/ridge losses on some composition and concrete roofs; impact damage to concrete from wind-borne debris

374 Allamanda, Burnt Store Meadows Development, Punta Gorda

TOTAL COUNT—11 homes viewed

ROOF SYSTEMS—One concrete tile, ten composition shingle

WALL CONSTRUCTION—Masonry stucco

NOTED DAMAGE—Tile—one with partial damage; composition shingle—seven with no damage and three with partial damage; ridge/hip losses; some field shingle loss

CAUSES OF ROOF DAMAGE—Blow-off from high winds, as well as impact by wind-borne debris

23146 Adella, Punta Gorda Isles

TOTAL COUNT—Seven homes viewed

ROOF SYSTEMS—Five composition shingles, two covered with blue tarps (unknown)

WALL CONSTRUCTION—Masonry stucco

NOTED DAMAGE—Composition—two with no damage, one with minor damage; "blue tarp"—two with partial damage; ridge/hip loss; gable ends damaged

CAUSES OF ROOF DAMAGE—Not investigated

19155 Punta Gorda, Punta Gorda Isles

TOTAL COUNT—Nine homes viewed

ROOF SYSTEMS—Eight composition shingle, one concrete tile

WALL CONSTRUCTION—Masonry

NOTED DAMAGE—Tile—one with minor damage; composition shingle—four with no damage, one with minor damage, two with partial damage, and one with major damage. Tile damage was at gable ends; shingle loss in field and at some ridges

CAUSES OF ROOF DAMAGE—Not investigated

14459 Sturkie, Punta Gorda

TOTAL COUNT—Four homes viewed

ROOF SYSTEMS—Three composition tile, one unknown

WALL CONSTRUCTION—Siding and masonry stucco

NOTED DAMAGE—None

CAUSES OF ROOF DAMAGE—Not applicable

20160 Vanguard, Port Charlotte

TOTAL COUNT—13 homes viewed

ROOF SYSTEMS—11 composition shingle, one barrel tile, one composition shingle with solar panels

WALL CONSTRUCTION—Masonry stucco

NOTED DAMAGE—Composition shingle—11 with no damage, 1 with minor damage; tile—1 with no damage; hip / ridge caps damaged

CAUSES OF ROOF DAMAGE—Not investigated

4477 Colleen, Port Charlotte

TOTAL COUNT—19 homes viewed

ROOF SYSTEMS—Nine tile (barrel and flat), ten composition shingle

WALL CONSTRUCTION—Masonry stucco

NOTED DAMAGE—Tile—two with no damage, three with minor damage, three with partial damage; composition shingle—four with no damage, five with minor damage, one with partial damage; damage occurred at ridge, hip, and field areas

CAUSES OF ROOF DAMAGE—Wind-borne debris

3239 Daytona (Harbor Heights), Port Charlotte, FL

TOTAL COUNT—12 homes viewed

ROOF SYSTEMS—11 composition shingle; one through-fastened metal

WALL CONSTRUCTION—Masonry stucco

NOTED DAMAGE—Composition shingle—seven with no damage, one with minor damage, two with partial damage, and one with major damage; metal—one with major damage; damage occurred at edges, eaves, gables, and ridges

CAUSES OF ROOF DAMAGE—Metal roof failed because of the sub-frame; i.e., the retrofitted metal roof system failed and was blown off the main structure in whole sections.

General Summary

Based on the detailed on-site investigative reports and ten quick roof surveys, most failures appeared to be due to poor construction methods. It is notable that this area had not experienced a hurricane of this magnitude in over 40 years.

Most roof damage started at a corner, ridge, rake edge, or eave overhang and progressed across the roof. Some observed failures used older asphalt shingles installed with staples. Some standing seam metal roofs exhibited failure of lighter than normal-gauge clips.

Wind-borne debris impacting concrete or clay tile caused extensive damage surrounding the point of impact. The loosened tiles were then subject to lifting and becoming wind-borne debris, causing more damage to roofs and walls. Some roofs had visible impact damage from wind-borne debris.

Damage often appeared to be random, e.g., a severely damaged house would be across the street from one with only minor damage. Although a structure’s wind resistance is a complex product of design, materials, and workmanship, an additional factor was the surrounding terrain. Strong winds blowing across open terrain generally caused the most severe damage. Buildings that were either partially or fully blocked by trees or other structures tended to survive with less, if any, damage.

While roof shape (gable versus hip) may have influenced the quantity of damage, damage was noted on both profiles. There was limited evidence of building envelope breaches. In those few instances, only two resulted in structural damage (loss of some roof deck panels and/or roof structure).

One building had a new steep slope roof retrofitted over the original low slope roof, and the newer roof separated from the house at the truss-to-wall connectors.

PHOTOGRAPHS OF ROOF DAMAGE

22377 Peachland Blvd., Port Charlotte

7-01-1. Peachland—garage door blow-out.

7-01-2. Peachland roof with sheathing loss.

7-01-3. Peachland—sheathing fasteners.

7-01-4. Peachland—sliding glass door.

22365 Peachland Blvd., Port Charlotte

7-02-1. Peachland—front view from street.

7-02-2. Peachland—alternate front view.

7-02-3. Peachland—minor roof damage.

7-02-4. Peachland—eave damage.

24123 Peachland Blvd., Port Charlotte

7-03-1. Publix mall Kings Highway—minor damage.

7-03-2. Publix mall Kings Highway—minor damage.

7-03-3. Publix mall Kings Highway—hip damage.

7-03-4. Publix mall Kings Highway—parapet.

530 Torrington Street, Port Charlotte

7-04-1. Torrington—concrete tile damage.

7-04-2. Torrington—concrete tile eave damage.

7-04-3. Torrington—concrete tile hip damage.

7-04-4. Torrington—concrete tile mortar blobs.

1401 Tamiami Trail, Port Charlotte

7-05-1. AMSouth Bank—metal and gable damage.

7-05-2. AMSouth Bank—metal roof, fastener spacing.

7-05-3. AMSouth Bank—metal roof, fastener clips damage.

7-05-4. AMSouth Bank—metal roof with tile impact points.

19179 Aviation, Port Charlotte

7-06-1. 19179 Aviation—asphalt shingled roof.

7-06-2. 19179 Aviation—asphalt shingles.

7-06-3. 19179 Aviation—asphalt shingles.

7-06-4. 19179 Aviation—wind came from this direction (relatively open terrain).

19189 Aviation Court, Port Charlotte

7-08-1. 19189 Aviation—concrete tile with no damage.

7-08-2. 19189 Aviation—minor screen damage.

7-08-3. 19189 Aviation—concrete tile with no damage.

7-08-4. 19189 Aviation—concrete tile with no damage.

19198 Aviation Court, Port Charlotte

7-09-1. 19198 Aviation—metal with no damage.

7-09-2. 19198 Aviation—metal with no damage.

7-09-3. 19198 Aviation—metal with soffit damage.

7-09-4. 19198 Aviation—metal roof, window shutters.

Gulf Blvd., Boca Grande

7-10-1. Boca-Bay Club—wood shakes with minor damage.

7-10-2. Boca-Bay Club—wood shakes with minor damage.

7-10-3. Boca-Bay Club—winds came from this direction (open terrain and no obstructions).

7-10-4. Boca-Bay Club—wood shakes with minor damage; some hip and ridge blow-off.

HURRICANE IVAN INVESTIGATION

METEOROLOGICAL INFORMATION

Hurricane Ivan made landfall early on September 16, 2004, east of Pensacola, Florida, with maximum wind gusts of about 120 mph. The wind speeds used in this report are from NOAA, ARA, and other sources. Definitive "official" wind speeds are not available at the time of this writing.

Appendices D and E are wind swath maps showing approximate maximum wind velocities experienced as Ivan made landfall and traveled inland to the north and northeast. Both maps show wind velocities at a height of 33 feet (10 meters) in open terrain (Exposure C).

Appendix D contains one of the "experimental research product" maps from the NOAA Surface Wind Analysis website (www.aoml.noaa.gov/hrd/Storm_pages) shortly after Ivan made landfall. It shows projected maximum 1-minute sustained wind velocities.

Appendix E was provided to RICOWI/Oak Ridge National Laboratory by ARA (www.ara.com) and essentially is an updated version of the preliminary NOAA data. Following the NOAA data, this is a 3-second gust wind speed map and is the basis for the wind speeds in the text. Based on the ARA data, maximum wind gusts at the 70 study sites ranged from 100 to 120 mph.

According to ASCE-7-02, **"**Minimum Design Loads for Buildings and Other Structures," design using 3-second gust wind speeds for this same area ranges between 130 mph and 140 mph. Maximum wind velocities experienced at the 70 study sites are therefore believed to be below ASCE-7-02 design levels.

FIELD INVESTIGATIONS

The Hurricane Ivan field investigations in the following sections are divided into low slope and steep slope systems. They are presented in the following order:

Low Slope Systems
- Team 1
- Team 2
- Team 4
- Team 5

Steep Slope Systems
- Team 3

HURRICANE IVAN

LOW SLOPE ROOF SYSTEMS

HURRICANE IVAN: TEAM 1

OVERVIEW

The members of Team 1 were assigned the task of gathering data on sprayed polyurethane foam (SPF) roof systems. The team was unable to identify any locations in the Pensacola area with SPF roofing. As a result, the team conducted investigations of low slope roof systems.

Team 1 Members

Robb Smith, Report Writer
Tom Kelly, Photographer
Phil Mayfield, Data Recorder
Jason Smart, Sample Collector/Photographer

Scope

During September 23–25, 2004, the team visited sites in and around the city of Pensacola, including Navarre Beach and Navarre. The focus was to visit “essential facilities” with low slope roofs. The following report summarizes the field data that were obtained.

Building Construction

There were an equal number of steel and concrete decks (six of each), plus one cementitious wood fiber (CWF) deck. Roof systems examined included built-up roofing (BUR), modified bitumen (MB), and single-ply (PVC, TPO, EP, and EPDM)—both mechanically fastened and fully adhered. Four roofs had lightweight insulating concrete (LWIC) decking. Edge conditions included parapet heights of 3 ft., as well as metal edges. Roof heights ranged from 10 to 210 ft. above the ground.

General Building Information

Facility	City	Roof height	Type structure	Area (ft.^{2})	ASCE exposure category	Deck type	Roof assembly	Extent of damage
Judicial Ctr. 2nd	Pen.	20 ft	Office	26,960	B	Concrete	LWIC/MB	Extensive
Judicial Ctr. Top	Pen.	75 ft	Office	18,500	B	Concrete	LWIC/MB	Extensive
South Trust Bank	Pen.	65 ft	Office	16,200	B	Steel	LWIC/BUR	Extensive
Fire Station #3	Pen.	20 ft	F.S.	5,390	B	Concrete	MB	Minor
Fire Station #6	Pen.	20 ft	F.S.	5,390	B	Concrete	MB	Extensive
Winn-Dixie Foods	Pen.	25 ft	Grocery	38,000	B	Steel	BUR	Minor
Gulf Power	Pen.	40 ft	Office	12,825	B	Concrete	PVC 1-ply	Minor
Gulf Power 2	Pen.	10–15 ft	Office	18,640	B	CWF	PVC 1-ply	None
Pensacola City Hall	Pen.	75 ft	Office	11,904	B	Steel	MB	Extensive
AmSouth Bank	Pen.	60 ft	Office	13,587	B	Steel	TPO 1-ply	Minor
Best Buy	Pen.	30 ft	Retail	93,625	B	Steel	EP 1-ply	Extensive
Navarre Towers	N.B.	130 ft	Condos	12,000	B	Steel	EPDM 1-ply	Minor
Beach Colony	N.B.	210 ft	Condos	9,000	B	Concrete	EP 1-ply	None
Total	13			282,021				

Roofing Materials Encountered

The field team was able to identify and evaluate the following roofing materials:

- MB—Asphalt MB roof membrane
- BUR—Asphalt built-up roof membrane
- Polyvinyl chloride (PVC)—Thermoplastic single-ply membrane
- Thermoplastic polyolefin (TPO)—Thermoplastic single-ply membrane
- Ethylene-propylene (EP)—Thermoplastic single-ply membrane
- Ethylene propylene diene monomer (EPDM)—Thermoset elastomeric single-ply membrane

Noted Damage

Most damage was related to perimeter problems. The SouthTrust Bank building lost its gravel-surface BUR and approximately 15% of the steel deck after three of the bank's windows were broken, pressurizing the building. Gravel from this roof was blown downwind onto the Judicial Center. This gravel almost certainly caused the window damage noted there.

One of the most significant roof losses was at the Judicial Center. It appeared that after the building was pressurized from winds coming through broken windows, air traveled up into the roof assembly through the 4-in. joint between the parapet and concrete deck, as well as through various penetrations in the deck. The positive pressure lifted the membrane loose from its mechanical attachment to the LWIC deck, blowing the membrane back and exposing the deck in many places. At Pensacola City Hall, the 700-ft^2 penthouse containing the building's telephone switch and other electrical systems was nearly destroyed. In contrast, no damage was noted on the a fully-adhered single-ply roof at Beach Colony condominiums, a 21-story building on Navarre Beach at Santa Rosa Island. Navarre Beach is approximately 50 miles east of Pensacola. Damage from wind-borne debris or other mechanical damage was seen on all roofs except at Beach Colony.

Conclusions

Inclusion of air barriers at penetrations of the roof deck, and at perimeters, should be considered by roof designers where high-wind exposures[1] exist. When a building becomes pressurized due to openings in the wall, air leakage below the roof membrane may cause or contribute to membrane damage or blow-off. Pull tests of membrane fasteners being considered for use in lightweight insulating concrete should always be considered as a test incorporated into roof system design, especially in re-roofing scenarios where the LWIC may be dry, with little holding power. Pull tests of fasteners used in existing LWIC should be considered for addition into the Building Code as a requirement prior to reroofing. The structural condition of the LWIC should be examined at several locations to determine its condition. Gravel-surfaced or stone-ballasted roof systems should comply with ANSI/SPRI RP-4 as set forth in the Building Code.

[1] High wind exposures are those areas with wind speeds greater than 110 mph as measured as a basic wind speed (3-second gust) See Figure 1609 in the International Building Code for illustration of U.S. Hurricane coastline.

Individual Roof Reports

1.01 Judicial Center, 190 Governmental Center, Pensacola

TYPE OF STRUCTURE—Office building

EXPOSURE—C

WALL CONSTRUCTION—Concrete

ROOF SYSTEM—Mineral-surfaced MB, torch-applied

ROOF HEIGHT—20–75 ft.

AREA—Second floor: 26,960 ft^2; fifth floor: 18,500 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—LWIC over structural concrete

WIND SPEED—110–120 mph

East elevation of the Judicial Center.

NOTED DAMAGE—60% of roof damaged with 30% of roof membrane blown off or delaminated.

DAMAGE INITIATION AND PROPAGATION—Several large windows at windward end of building were shattered from wind-borne debris, pressurizing the building. Gravel from the AmSouth Bank building across the street, and upwind, was found on and around this roof. Negative air pressure from above and positive air pressure from below were the direct cause of blow-off of much of the membrane and displacement of sections of the LWIC.

COMMENTS—Some roofs dated from around 1999, according to building staff. This building was within two blocks of Pensacola Bay. Inclusion of air barriers at parapets and penetrations likely would have reduced damage.

1.02 SouthTrust Bank, 316 S. Baylen St., Pensacola

TYPE OF STRUCTURE—Office building

EXPOSURE—B

WALL CONSTRUCTION—Wood

ROOF SYSTEM—Gravel-surfaced BUR

ROOF HEIGHT—65 ft.

AREA—16,200 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—LWIC over steel pan

WIND SPEED—110–120 mph

NOTED DAMAGE—Building sustained 100% roof loss, most from blow-off. Approximately 15% of the deck was also blown off.

Northwest corner of SouthTrust Bank (side nearest the Judicial Center).

DAMAGE INITIATION AND PROPAGATION—Windows at the southeast (windward) corner were blown out, pressurizing the building. Roof membrane and deck loss started at the same corner.

COMMENTS—Gravel from this roof blew across the street and broke windows in the Judicial Center, causing similar damage to decking and roof membrane. Date of construction or last roofing application was not determined. Building was a few blocks from Pensacola Bay.

1.03 Fire Station 3, Pensacola

TYPE OF STRUCTURE—Fire station

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF SYSTEM—MB

ROOF HEIGHT—16–20 ft.

AREA—5,390 ft^2

ROOF SLOPE—¼":12"

Fire Station 3.

ROOF DECK—Concrete plank

WIND SPEED—110–120 mph

NOTED DAMAGE—Roof sustained less than 5% damage, mostly related to metal edging coming loose at cleats; awning also blew off.

DAMAGE INITIATION AND PROPAGATION—Fascia cleat system failed, initiating the damage. Design of the fascia system was not in accordance with the current Code requirement provided in ANSI/SPRI ES-1.

COMMENTS—Date of construction or last roofing application was undetermined.

1.04 Fire Station 6, Pensacola

TYPE OF STRUCTURE—Fire station

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF SYSTEM—BUR

HEIGHT—16–20 ft.

AREA—5,390 ft^2

ROOF SLOPE—¼":12"

Fire Station 6.

ROOF DECK—LWIC over structural concrete

WIND SPEED—110–120 mph

NOTED DAMAGE—Roof sustained less than 40% damage (upper roof blow-off). Approximately 30% of metal edge flashings were damaged.

DAMAGE INITIATION AND PROPAGATION—Lack of non-continuous cleat in metal edge flashing allowed metal edge to be blown back by the wind. Subsequently, the MB peeled off. Large sections of membrane were examined on the ground.

COMMENTS—Date of construction or last roofing application was not determined, although roofing materials appeared to be less than 2 years old.

1.05 Winn-Dixie Foods, 13019 Sorrento Rd., Pensacola

TYPE OF STRUCTURE—Grocery store

EXPOSURE—B

WALL CONSTRUCTION—Steel

ROOF SYSTEM—BUR over rigid insulation

ROOF HEIGHT—25 ft.

AREA—38,000 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—Steel

WIND SPEED—110–120 mph

Winn-Dixie grocery store.

NOTED DAMAGE—Roof sustained less than 10% damage, primarily related to edge flashing and damage from missiles.

DAMAGE INITIATION AND PROPAGATION—Roof damage occurred at the southeast corner when metal edge came loose from the continuous cleat, allowing air under the membrane. The BUR peeled back from the edge approximately 55 ft. Further damage from peeling of membrane was blocked by a 35-ft.-long curbed heating, ventilating, and air-conditioning unit.

COMMENTS—It appears that metal edging may not have been fully engaged into the incontinuous cleats.

1.06 Gulf Power 1, 75 N. Pace Blvd., Pensacola

TYPE OF STRUCTURE—Office building

EXPOSURE—B

WALL CONSTRUCTION—Concrete

ROOF SYSTEM—PVC single-ply mechanically fastened with batten bar

ROOF HEIGHT—20 ft.

AREA—8,288 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—Plywood

WIND SPEED—110–120 mph

Gulf Power building 1: view of SW corner.

NOTED DAMAGE—Roof sustained less than 5% damage, primarily resulting from mechanical damage from wind-blown equipment.

DAMAGE INITIATION AND PROPAGATION—Initial wind from the east blew off most of the unprimed galvanized metal edge flashing, which failed, initiating the damage. Design of the fascia system was not in accordance with the current Code requirement provided in ANSI/SPRI ES-1.

COMMENTS—This building was one of 18 in the condominium project. Other adjacent buildings experienced similar damage. Date of construction or last roofing application was not determined. Building was located approximately 1 mile north of the Peace River. Evidence suggests that winds may have blown into building from both east and west as the storm traveled through. The roof of an adjacent single story property (in windward direction) with a BUR also was blown off.

1.07. Gulf Power 2, 2200 W. Chase, Pensacola

TYPE OF STRUCTURE—Office building

EXPOSURE—B

WALL CONSTRUCTION—Masonry

ROOF SYSTEM—PVC single ply, fully adhered

ROOF HEIGHT—10–15 ft.

AREA—18,640 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—CWF

WIND SPEED—110–120 mph

Gulf Power building 2: view of the east side.

NOTED DAMAGE—Roof sustained less than 5% damage, all from wind wind-borne debris.

DAMAGE INITIATION AND PROPAGATION—Damage was a result of wind-borne debris.

COMMENTS—Dates of construction and of last roofing application were not determined.

1.08 Pensacola City Hall, 180 W. Government St., Pensacola

TYPE OF STRUCTURE—Office building

EXPOSURE—C

WALL CONSTRUCTION—Masonry

ROOF SYSTEM—MB, mechanically fastened

ROOF HEIGHT—75 ft.

AREA—11,904 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—LWIC over steel pan

WIND SPEED—110–120 mph

City Hall: view of the south (bay) side.

NOTED DAMAGE—Roof sustained 60% damage. It had poorly adhered wall flashings, and the mechanical fasteners were detached from the LWIC, resulting in blow-off.

DAMAGE INITIATION AND PROPAGATION—Negative and positive pressure occurred. Windows were blown out at southeast corner.

COMMENTS—Dates of construction and of the last roofing application were undetermined. Building is one block north of the bay.

1.09 AmSouth Bank, 70 N. Baylen, Pensacola

TYPE OF STRUCTURE—Office building

EXPOSURE—B

WALL CONSTRUCTION—Masonry curtain wall

ROOF SYSTEM—TPO, single ply, mechanically fastened

ROOF HEIGHT—55 ft.

AREA—13,587 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—CWF

WIND SPEED—110–120 mph

AmSouth Bank: west side.

NOTED DAMAGE—Roof sustained 15–20% damage, e.g., billowing wall flashings, loosened field membrane fasteners, partially detached metal coping, and punctures from wind-borne missiles.

DAMAGE INITIATION AND PROPAGATION—Wall flashings, field membrane, and metal coping. Design of the coping system was not in accordance with the current Code requirement provided in ANSI/SPRI ES-1.

COMMENTS—Dates of construction or last roofing application were undetermined. Location is less than six blocks north of the bay.

1.10 Best Buy, 5480 N 9th Ave., Pensacola

TYPE OF STRUCTURE—Retail

EXPOSURE—B

WALL CONSTRUCTION—Concrete masonry unit

ROOF SYSTEM—EP single ply, fully adhered

ROOF HEIGHT—30 ft.

AREA—98,625 ft^2

ROOF SLOPE—½":12"

ROOF DECK—Steel

WIND SPEED—110–120 mph

Best Buy: northwest side.

NOTED DAMAGE—80% of roof membrane was blown off. Entire electronic inventory was damaged.

DAMAGE INITIATION AND PROPAGATION—Examination of remaining membrane revealed no evidence of mechanical attachment at the base of walls. Wall flashing was adhered, with no mechanical fasteners being used. Facer delaminated from insulation boards. Roof membrane, with insulation facer attached, was available for examination in the parking lot.

COMMENTS—Roof reportedly was installed in 2002.

1.11 Navarre Towers, 8271 Gulf Blvd., Navarre

TYPE OF STRUCTURE—Condominiums

EXPOSURE—C

WALL CONSTRUCTION—Wood

ROOF SYSTEM—EPDM single ply, fully adhered

ROOF HEIGHT—130 ft.

AREA—12,000 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—Undetermined

WIND SPEED—90–100 mph

Navarre Towers: north side.

NOTED DAMAGE—Roof sustained less than 10% damage; loss of coating; plastic traffic pad blow-off; wind-borne missile punctures.

DAMAGE INITIATION AND PROPAGATION—Delamination was most evident at the southwest corner of the roof from limited loss of membrane adhesion (one corner was approximately 35×14 ft).

COMMENTS—Dates of construction and of the last roofing application were undetermined.

1.12 Beach Colony, 8515 Gulf Blvd., Navarre

TYPE OF STRUCTURE—Condominiums

EXPOSURE—C

WALL CONSTRUCTION—Concrete

ROOF SYSTEM—EP single ply, fully adhered

ROOF HEIGHT—210 ft.

AREA—9,000 ft^2

ROOF SLOPE—¼":12"

ROOF DECK—Concrete

WIND SPEED—90–100 mph

Roof of Beach Colony.

NOTED DAMAGE—Roof sustained less than 5% damage, mainly windborne missile punctures.

DAMAGE INITIATION AND PROPAGATION—What little damage there was appeared to be the predictable consequence of sharp, high-speed wind-borne debris impacting the single-ply membrane.

COMMENTS—Building constructed in 2002, according to local sources.

PHOTOGRAPHS OF ROOF DAMAGE

The following photographs illustrate the types of roofs and damage conditions that were viewed during this field investigation.

Judicial Center

1-01-1. A 4-in. gap at wall and deck allowed positive pressure to get under the roof membrane and decking. Glass fiber board insulation was found in the gap.

1-01-2. Wire lath was not embedded in LWIC during original placement, allowing air to travel between the pours of LWIC.

1-01-3. Membrane blown off with fasteners intact This may indicate poor holding power of LWIC.

1-01-4. Many fasteners were found in mostly closed position—an indication of poor holding power of split-shank fastener in dry LWIC.

1-01-5. Fastened base sheet with 2-ply MB membrane cut through by wind-borne debris.

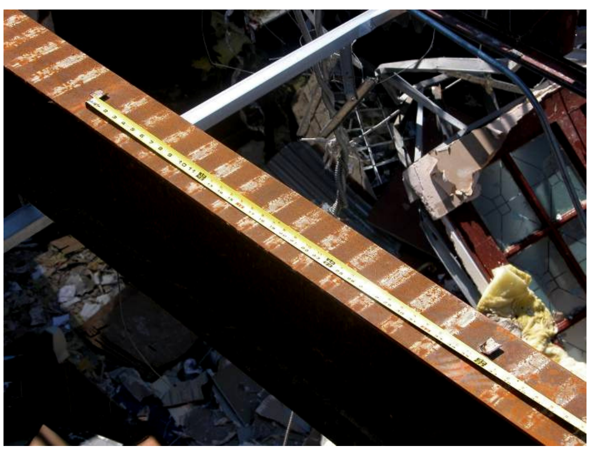
SouthTrust Bank

1-02-1. Southeast corner office on sixth floor where windows blew out, pressurizing the building.

1-02-2. Steel deck and LWIC blown off at southeast corner.

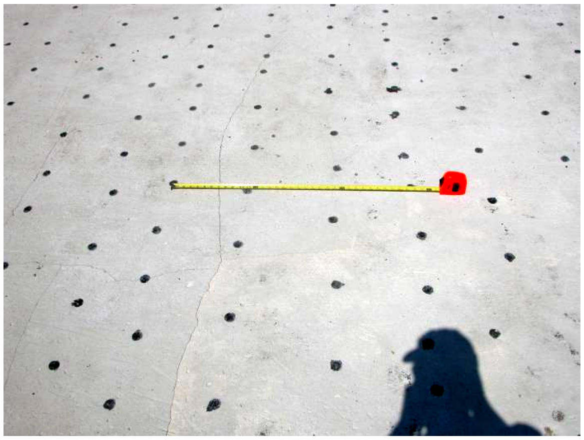
1-02-3. Deck blow-off site at the southeast corner.

1-02-4. LWIC fastener embedded in LWIC.



1-02-5. Attachment of the steel deck to the joist was welded at 36 in. o.c.

1-02-6. Attachment point on joist at 36 in. o.c.



1-02-7. The BUR base sheet was fastened at an average of 11 in. o.c. at side laps and 15 in. o.c. in two rows 12 in. from edges.

Fire Station 3

1-03-1. Partial view of the west side.

1-03-2. Partial view of the east side.

1-03-3. Damage was limited to edge metal pulled loose from cleat. Note that part of the continuous cleat is missing on the right side.

Fire Station 6

1-04-1. Edge flashing damage on the top roof resulted in complete membrane loss.

1-04-2. The only section of membrane remaining was found at the leeward edge. The perimeter nailer could not be located.

1-04-3. Damage included portions of the LWIC deck.

1-04-4. Examination of metal edge flashing revealed fastening at distances of greater than 8 in. o.c.

Winn-Dixie Foods

1-05-1. Metal edge was nailed randomly at distances greater than 8 in. o.c. It was not securely fastened to the continuous cleat. Fascia hook was only ½ in. long.

1-05-2. Flashings at equipment curbs were damaged.

Gulf Power 1

1-06-1. View of the northwest corner. Dish antenna was installed using non-penetrating concrete block ballast, without curb or mechanical attachment.

1-06-2. View of the southwest corner, showing additional membrane fastening at the corners.

1-06-3. Equipment was installed with steel cables to hold it in place. No equipment moved from mounting position.

Gulf Power 2

1-07-1. The only puncture damage from wind-borne debris was observed on this mechanically fastened single-ply PVC system.

1-07-2. View to the southwest. No damage was observed on the fastening mechanisms of this batten-fastened single-ply membrane.

Pensacola City Hall

1-08-1. Heat-welded wall flashing blew off. It was not fully adhered to the concrete masonry unit wall.

1-08-2. Wall/roof blow-out of the penthouse was due to wind infiltrating through metal louvers (top, center) and pressurizing the interior. This resulted in complete loss and contributed to airborne damage to surrounding buildings.

1-08-3. Steel roof decking from the penthouse contributed to MB roof and flashing damage.

AmSouth Bank

1-09-1. Damage to equipment screens caused many membrane punctures. Equipment dislodged from curbs also resulted in membrane punctures.

1-09-2. Coping was not installed with continuous cleats. Portions were loosened or blown off.

1-09-3. Extensive masonry curtain wall damage on the west (leeward) side of the building. Significant corrosion of steel connections was evident.

Best Buy

1-10-1. Loose section of old thermoplastic single-ply membrane. The fully adhered membrane peeled from the insulation facer. Black EPDM (background) was used as a temporary membrane.

1-10-2. Section of the old membrane.

Navarre Towers

1-11-1. One small area on the south side, near the center of the roof, appears to be wind-damaged. This was the extent of observed roof damage. OSB was mechanically fastened to the deck, and the EPDM membrane was fully adhered to the OSB.

1-11-2. Penthouse coping was installed without a continuous cleat and was deflected in some areas. EPDM roof membrane was wrapped over the parapet and mechanically fastened.

1-11-3. Most air-conditioning condenser units stayed in place with this minimal fastening at four corners.

1-11-4. Yellow "spaghetti" traffic pads delaminated and became detached from the EPDM.

Beach Colony

1.12-1 – North wall.

1.12-2 – No damage was observed to this fully adhered thermoplastic single-ply membrane.

HURRICANE IVAN: TEAM 2

OVERVIEW

Team 2 focused on low slope roof coverings on essential facilities, schools, post offices and other structures primarily in the Pensacola, Florida, area.

Team 2 Members

Dave Roodvoets, Report Writer
John Goveia, Photographer
Eric Haefli, Sample Collector
Jason Mooney, Sample Collector
Patty Wood-Shields, Data Recorder

Roofing Materials Viewed

The team was able to investigate the following types of roof systems:

- Granular surface modified bitumen
- Ballasted Hypalon single-ply membrane
- Thermoplastic Olefin (TPO) single-ply membrane
- Built-up roof (BUR) aggregate surface
- Polyvinyl chloride (PVC) single-ply membrane
- Protected membrane (IRMA-PMR)

SUMMARY OBSERVATIONS

No apparent structural issues were noted on the essential buildings. Many buildings lost cladding or windows, resulting in damage to the roofs. Many air-handling units were either displaced intact from their initial mounting positions or came apart, with the debris hitting the roof and creating damage. Some level of edge metal damage occurred on most buildings. Roofs were damaged in the expected areas, on the sides exposed initially to the high winds. Many roofs survived. Below are summary observations for each roof surveyed.

INDIVIDUAL BUILDING REPORTS

2.01 West Florida Hospital Ancillary Building, 8383 N Davis Highway,

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—Concrete panels recovered with exterior insulation finished system (EIFS) cladding

ROOF SYSTEM—Granular surface modified bitumen BUR of at least three plies

ROOF SLOPE—¼":12"

ROOF DECK—Cast-in-place structural concrete on a steel pan

WIND SPEED—110–120 mph

COORDINATES—N30°27.816′—W87°13.427′

CONSTRUCTION—The ancillary building, one of many on the site, is mostly of steel frame construction. The wall cladding is the original rock aggregate precast concrete exterior panels that had been retrofitted with an EIFS exterior cladding system. The building section was constructed in 1974 and had been re-roofed with a modified bitumen system within the last 2 years. The roof deck is at about 90 ft. above grade and is cast-in-place structural concrete over a metal pan.

The Escambia Bay inlet is observable to the east and south from the roofs, yet the surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with a height of surface roughness of about 25–30 ft. above grade. Streets and parking lots create open areas on the east and west sides of the structure; it also was adjacent to higher-elevation structures to the south and northeast.

NOTED DAMAGE—The primary damage to this roof was from wall panel debris primarily blown off the taller adjacent building's elevator shaft cladding and penthouse cladding, leaving an obvious damage path as if material tumbled across the roof, creating punctures. There were also punctures from air-handling units that had been displaced.

DAMAGE INITIATION—All of the roof damage was due to debris or loss of coping that had dislodged. The membrane was entirely in place with no sign that it had lifted or otherwise been harmed.

COMMENTS—One facility maintenance person, who was on site during the event, indicated the winds were initially from the east, and then quickly changed from the south. This section of roof was somewhat protected from the primary winds by a taller stairwell structure and a taller building to the southwest. There would be no significant repairs if this roof had not been punctured by debris; however, a large section of the EIFS wall from the adjacent structure (2.03) above and windward of this roof section became dislodged and landed mostly on this roof. There is a high probability that the building below the roof deck was pressurized, as there was significant loss of cladding and windows in the six floors below. The load on the roof membrane may have been resisted because of the impermeability of the deck assembly/ceiling construction, or because pressures were relieved by the cladding loss on the stairwell tower walls.

2.02 West Florida Hospital, East Patient Hospital, 8383 N. Davis Highway

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—Concrete panels recovered with EIFS cladding

ROOF SYSTEM—Hypalon single-ply membrane ballasted with stone

ROOF SLOPE—¼":12"

ROOF DECK—Cast-in-place concrete

WIND SPEED—110–120 mph

CONSTRUCTION—The building, one of many on the site, consists mostly of steel frame construction with original rock aggregate precast concrete exterior panels retrofitted with an EIFS exterior cladding system. The roof deck, which is about 30 ft. above grade, appears to be cast-in-place concrete. This roof has a gravel stop edge.

The Escambia Bay inlet could be seen to the east and south from the roofs, yet the surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with a height of surface roughness of about 25–30 ft. above grade. Streets and parking lots create open areas on the east, northeast, south, and southeast side of the structure.

ROOF MEMBRANE SYSTEM—The membrane was a loose-laid ballasted white reinforced elastomeric sheet single-ply membrane (Hypalon). The ballast was similar to ASTM 448 #4 or larger (average 1.5 in. with stones up to 2 in.) The membrane was installed over tapered isocyanurate insulation.

NOTED DAMAGE—No membrane damage was noted. There was a small amount of gravel scour at the windward side, at corners, and around penthouses. There were no signs that gravel had left. the roof. Some of the partially adhered, ½- in.-thick rubber walk pads had become loose from the membrane; some may have blown off the roof. A 30–40 ft. segment of the snap on the fascia edge metal cover had become disengaged from its cleat and had blown off. An exhaust fan had also blown off the roof.

DAMAGE INITIATION—The shop-fabricated metal edge system, including a surface-mounted vertical cleat and fascia cover, was installed over an existing gravel stop. The cleat was continuous, was fastened through the vertical surface, and was a thin gauge that exhibited profile deformation that did not resist the bending from forces exerted by the fascia.

COMMENTS—One facility maintenance person, who was on site during the event, indicated the winds were initially from the east, and then quickly changed from the south. This roof essentially survived the storm. There were no known leaks, and the ballast remained on the roof. Ballast scour may occur, based on previous wind studies, for winds over 115 mph at this building height. The damage to the edge was repairable. The section of the hospital had been closed because the windows in the east-facing wall leaked so badly that water was blowing into the patient rooms. They expected to have the area back in operation as soon as the rooms were dried out.

2.03 Tower Medical Building, 8383 N. Davis Highway

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—Glass and EIFS panels

ROOF SYSTEM—TPO single-ply membrane recover system

ROOF SLOPE—¼":12"

ROOF DECK—Steel

WIND SPEED—110–120 mph

CONSTRUCTION—This steel frame building, completed in 1984, is about 140 ft. above grade. It has a steel roof deck and a short parapet curb from a height of approximately 8–12-inches. The exterior walls are glass and EIFS. Several of the glass and EIFS panels were blown out. An adjacent elevator tower lost its entire cladding below and up to the roof level.

The Escambia Bay inlet is observable to the east and south from the roofs, yet the surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with a height of surface roughness of about 25–30 ft. above grade. Streets and parking lots create open areas on the east, northeast, south and southeast side of the structure across the street as well as adjacent to the structure.

ROOF MEMBRANE SYSTEM—The membrane was a mechanically attached white reinforced elastomeric sheet TPO single-ply membrane. From the top down, it was a recover system over a steel deck: 5/8-in. gypsum board, 5-in. molded expanded polystyrene, flameguard sheet, unreinforced PVC, 5/8-in. greenboard (gypsum), 45-mil. TPO. Field sheets were 6 ft. wide, fastened 12 in. on center (o.c.) and two 3-ft.-wide perimeter sheets were used, fastened 12 in. o.c. using #12 screws and

2-in.-diameter barbed plates. Fastening of the membrane into the roof deck along and parallel to the parapet used screws and plates.

NOTED DAMAGE—The membrane was under billowing-type uplift in the southeast corner, resembling a “scour type” shaped pattern from the east wall near the southeast corner. The telltale sign was classic membrane attachment plate (round) deformation along the leeward edge of the plates. EIFS blowing off elevator walls and mechanical penthouse walls had punctured the membrane in more than 150 locations (as well as on the roof of 2.01). The metal edge had come off in several areas. The exterior cladding on the building was missing just below the roof, so air entered directly under the deck. Many small pieces of wind-borne debris (probably from the elevator tower penthouse and perimeter wall) had blown in under the membrane on the east and south portions of the roof. There was building content damage from roof leaks and from the many breaches in the exterior cladding on the walls. Several air-handling units were off their bases. The membrane was also torn in the upwind area. Sheet metal coping was displaced along the leading edge in the southeast corner.

DAMAGE INITIATION—The membrane had been under uplift in the southeast corner. The exterior wall cladding systems had openings that failed at various locations, and provided openings for pressurization of the penthouse structure and the building. Debris from the wall claddings of the elevator shaft and the penthouse punctured the membrane in many places. Coping was inadequately fastened and dislodged.

COMMENTS—This was the highest roof in the area and although it technically is not an essential facility, it housed medical offices and clinics. The original membrane, sandwiched under gypsum board and insulation in the system, could be considered to act as an air retarder, at least in the field of the roof. However, because of the openings in the exterior wall surfaces, the loss of coping at the leading edge, and the use of screws and plates along perimeter edges (in lieu of termination bars), air infiltration beneath the top membrane would not be restricted. There was much damage to the building because of window and cladding failures. The core of the building was in operation within a few days, but the building needed substantial repairs. The structural system was apparently undamaged. There were louver openings in the mechanical penthouse walls, and there would have been louvers in the elevator shaft penthouse walls, both of which would be a design consideration for determining if those sections of the building would be considered enclosed or partially enclosed.

2.04 Baptist Hospital Main Building, 1000 W. Moreno

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—Steel frame, brick facade

ROOF SYSTEM—Granular cap sheet over BUR; newer roofs were modified bitumen

ROOF SLOPE—¼":12"

ROOF DECK—Concrete or lightweight on a steel pan

WIND SPEED—110–120 mph

COORDINATES—N30°27.745′—W87°13.863′

CONSTRUCTION—The building is steel frame construction with brick facade. Decks are concrete or lightweight concrete over steel pan. The roof is about 60 ft. above grade. There are about ten roof areas, interconnected off the original hospital tower building, which was constructed in 1949.

Surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with height of surface roughness of about 25–30 ft. above grade. Open areas on the west side of the structure are created by parking lots adjacent to the structure. Taller medical buildings are located directly to the north of the hospital.

ROOF MEMBRANE SYSTEM—The roof surfaces are generally granular cap sheet over BUR over perlite or fiberboard insulation, mopped to the decks. Newer roofs are granular modified bitumen sheets over 3-ply modified bitumen. A concrete helipad covered one section.

NOTED DAMAGE—The entire roofs of three elevator penthouse structures were completely displaced, but the fourth elevator penthouse roof was not damaged. A section of roof covering and insulation came off just above a staircase. Shop-fabricated perimeter metal was missing in several areas. There were some minor punctures due to debris.

DAMAGE INITIATION—Each of the elevator towers have wall louver openings just below the roof deck to provide pressure relief for elevator operation. A similar wall louver was observed just below the area of the roof membrane blow-off above the staircase. At one coping damage location observed, the perimeter metal had concealed fasteners in the standing seam at some locations, indicating the lack of edge fasteners. Other coping with fasteners 20–30 in. o.c. was measured. In another section, fasteners were only at the standing seam ends through cleats in the seam (as compared with top-through-fastened or fastened through the vertical turned-down surfaces).

COMMENTS—Most roof areas performed well with no damage. The small areas of blow-off were temporarily repaired within days. The elevator tower with the intact roof membrane system had a gypsum board ceiling attached to the bottom side of the roof deck, and all joints in the ceiling were taped. The louver openings in the elevator shaft walls would be a design consideration for determining if those sections of the building, would be considered enclosed or partially enclosed and pressures accommodated.

2.05 Baptist Hospital Medical Facility, T-3 Main Roof

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—Steel frame, brick facade

ROOF SYSTEM—BUR aggregate surfaced

ROOF SLOPE—¼":12"

ROOF DECK—Lightweight concrete

WIND SPEED—110–120 mph

CONSTRUCTION—The building is steel frame construction with a brick facade. The main roof is about 75 ft. above grade and has a gravel stop edge. A mechanical penthouse is located in the middle of the main roof. Pensacola Bay is observable to the south from the roof, yet the surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with a height of surface roughness of about 25–30 ft. above grade. Streets and parking lots create open areas on the west side of the structure. The building is the westward structure of three similar structures—all of equal height. The two adjacent, similar buildings are to the east and have cap sheet surfacing. The hospital, with a varying height of generally 60 ft., is located directly to the south.

ROOF MEMBRANE SYSTEM—A 4-ply BUR with a pea gravel aggregate surface over fiberglass insulation, mopped to the deck. The roof was installed in 1992.

NOTED DAMAGE—The exterior remained entirely intact, the system was 100% watertight, and there was no displacement. However, the aggregate pea gravel was scoured in classic patterns. Aggregate pea gravel was blown off this roof. There was reported damage to the windshields of cars parked nearby from the pea gravel and/or debris from this roof or the attached penthouse roof. A roof fan also was missing a cover on the main roof section.

DAMAGE INITIATION—About 50% of the aggregate pea gravel was not embedded into the asphalt surface. This unembedded aggregate surfacing was displaced and blew off the roof.

COMMENTS—This was one of three nearly identical buildings that make up the medical practice units of the hospital. All of these main roofs remained intact. However, some unembedded aggregate pea gravel is expected and common. There is no physical barrier on the roof, such as a parapet or wall, to stop gravel from being blown off the roof.

2.06 Baptist Hospital, Medical Facility, T-3 Penthouse Roof

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—Steel frame, brick facade

ROOF SYSTEM—BUR aggregate surface

ROOF SLOPE—¼":12"

ROOF DECK—Steel

WIND SPEED—110–120 mph

CONSTRUCTION—The penthouse is constructed of structural steel sheathed with steeply sloped standing seam metal roof covering. It has a small low slope roof section at the top elevation. The low slope roof is about 90 ft. above grade. Pensacola Bay and Escambia Bay inlet are observable from the roof to the south and west respectively, yet the surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with a height of surface roughness of about 25–30 ft. above grade. Streets and parking lots create open areas on the west side of the structure. The building is the westward structure of three similar structures—all of equal height. The two adjacent, similar buildings are to the east and have cap sheet surfacing. The hospital, with a varying height of generally 60 ft., is located directly to the south.

ROOF MEMBRANE SYSTEM—A 4-ply BUR with a pea gravel aggregate surface installed in 1992. The membrane was mopped to fiberglass insulation, mopped to the deck. The roof had a gravel stop edge that extended down over the metal roof covering. The metal covering is a utility-style, external fastened system over batt insulation over the steel support structure.

NOTED DAMAGE—Openings with daylight showing to the interior were observed with the penthouse structure at the hip corners. About 25 % of the roof along the entire windward east side was blown completely off the building. The low sloped roof edge metal was displaced from the upwind side. The membrane and the loose aggregate pea gravel damaged cars in the parking lot 60 to 120 feet west, to the leeward side of the building. The low slope roof edge metal was displaced from the upwind side. Four vent covers and one of two air-handling units on the low slope roof were blown off.

DAMAGE INITIATION—The penthouse structures are the highest points on the property and generally unobstructed from wind coming from the south–southeast. It is likely that the edge flashing failure on the low slope roof allowed the membrane system to peel from the insulation or the deck. It is also possible that the openings in the metal roof covering allowed positive pressurization, contributing to the loss of vent covers and one air-handling unit.

COMMENTS—This was one of three nearly identical buildings. All three buildings were the same height and shape and had a penthouse structure located in the middle of the main roof. The roofs on the other buildings' penthouses did not have a pea gravel aggregate surface but were granular surfaced. The louver openings and other points of air entry, such as at hip flashings in the metal covering, would be a design consideration for determining if those sections of the building would be considered enclosed or partially enclosed and the pressures accommodated. The penthouse structures of the two other similar buildings to the east also had louver openings and some damage.

2.07 Medical Office Building, Sacred Heart Hospital Complex, 5153 9th St.

TYPE OF STRUCTURE—Medical Office Building

EXPOSURE—B

WALL CONSTRUCTION—Steel frame, EIFS cladding

ROOF SYSTEM—PVC adhered

ROOF SLOPE—¼":12"

ROOF DECK—Lightweight insulating concrete (LWIC) over vented steel deck

WIND SPEED—110–120 mph

COORDINATES—N30°28.400′—N30°28.602′

CONSTRUCTION—The building is steel frame construction. The roof is approximately 75 ft. above grade. The exterior wall cladding is an EIFS system with a 30-in.-high parapet. Surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with height of surface roughness of about 25–30 ft. above grade. Open areas on the east, southeast, and south sides of the structure are created by streets and parking lots to the east and south, as well as adjacent to the structure. The hospital, with a varying height of generally 60 ft., is located directly to the southwest. This building is approximately one story higher in elevation above the other two buildings observed at the site.

ROOF MEMBRANE SYSTEM—The membrane is a reinforced fleece-backed PVC, fully adhered to a LWIC deck, over a ventilated (slotted) steel deck pan.

NOTED DAMAGE—Roof membrane with the LWIC had delaminated from the steel deck, and the membrane had delaminated from the LWIC and peeled back. Water had entered the building from the roof. The membrane had been laid back over the blow-off areas. Membrane had also peeled up the walls in the blow-off areas. There were more than 400 punctures of the membrane due to wind-borne debris from the EIFS system that blew off the mechanical penthouse walls, and damage from air-handling units that became displaced and blew across the roof.

DAMAGE INITIATION—The initialization point of the lifted and displaced membrane in the SE corner clearly was most severe along the south wall, but there was no obvious source for pressurization directly below the deck. A portion of the wall two floors directly below had some cladding displacement damage. There are also three overflow scuppers present in the damaged section, with one roughly centered in the damaged area; however, the scuppers were still in place and not torn out or lifted out along with the membrane. All of the other damage was due to punctures.

COMMENTS—This project could benefit from some more detailed forensic study. The cause of the roof membrane damage is not immediately obvious.

2.08 Main Hospital, Sacred Heart Hospital, 5151 9th St.

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—EIFS cladding

ROOF SYSTEM—BUR protected membrane

ROOF SLOPE—¼":12"

ROOF DECK—Lightweight concrete over steel

WIND SPEED—110–120 mph

CONSTRUCTION—The building is a medium to heavy mass type of construction with EIFS clad walls. This roof is 75 ft. above grade, and the roof edge is essentially a short perimeter curb with a coping. Surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with height of surface roughness of about 25–30 ft. above grade. Open areas on the east, southeast and south sides of the structure are created by streets and parking lots to the east and south, as well as adjacent to the structure. The hospital, with a varying height of generally 60 ft., is located directly to the southwest of site 2.07. This building is approximately one story lower in elevation than site 2.07.

ROOF MEMBRANE SYSTEM—This is a protected membrane (IRMA-PMR) system. It is based on a design style discontinued in the early 1980s, so the roof is believed to be over 20 years old. The membrane is a BUR. The insulation is loose-laid 1½-in. Styrofoam-extruded polystyrene (XEPS). It is ballasted with about 13–15 lb/ft.^{2} of ASTM D448 #4 ballast stone (average stone size of 1½-in. diameter with some stones as large as 2 in.). The roof edge is essentially a short perimeter curb with a sheet metal coping installed without the use of cleats. The southeast end has a mechanical screen resembling a parapet, as well as a raised structure.

NOTED DAMAGE—The membrane is entirely intact, and no ballast was observed or reported to have left the roof; but there were minor indications of ballast movement or displacement. The walk pads are a typical ½- to ¾-in.-thick, granule-surfaced asphaltic type, roughly 3×4 ft., adhered to the XEPS. Some walk pads were dislodged, but all appear to be on the roof. There was substantial loss of edge metal on the windward south side and on the opposite (north) side of the penthouse roof but very minor indications of ballast movement or displacement.

DAMAGE INITIATION—There was substantial metal coping loss on this roof. If the metal had remained in place, there would be little damage on the roof and there would not have been exposure to moisture intrusion except for the dislodged walk pads that do not compromise the watertightness of the roof.

COMMENTS—This style of ballasted roof, with roof edge curbs would no longer be a design consideration given the concern regarding wind-borne debris.

2.09 DePaul Building, Sacred Heart Hospital, 5147 9th St.

TYPE OF STRUCTURE—Hospital

EXPOSURE—B

WALL CONSTRUCTION—EIFS cladding

ROOF SYSTEM—Multi-ply BUR with granular cap sheet

ROOF SLOPE—¼–½":12"

ROOF DECK—LWIC on a steel pan

WIND SPEED—110–120 mph

CONSTRUCTION—The building is steel frame construction with EIFS cladding. This roof is about 75 ft. above the adjacent grade, but it is at a lower elevation than some surrounding buildings as it is on the down side of a hill. There is a parapet wall approximately 30–34 in. high around most sides. The deck is a steel pan with LWIC topping. Surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with height of surface roughness of about 25–30 ft. above grade. Open areas on the east, southeast, and south sides of the structure are created by streets and parking lots to the east and south, as well as adjacent to the structure. The hospital, with a varying height of generally 60 ft., is located directly to the north of this site. Because of terrain elevation changes at the site, this building is approximately one story lower in elevation than site 2.07. This building is actually at a lower terrain elevation than the first roof observed at this site—the ground elevation is one story down, with a varying building height of generally 75 ft. above grade.

ROOF MEMBRANE SYSTEM—Granular surfaced BUR with a checkerboard pattern venting base sheet, mechanically fastened with coated, spreading anchor leg fasteners into LWIC using “small plate” (rather than “large plate”) enhancement for greater tear resistance. A similar membrane was on the parapet wall surfaces, terminating under a counterflashing system approximately 24 in. above the roof membrane.

NOTED DAMAGE—The roof covering had already been temporarily replaced, but the original membrane debris was still on the roof, providing for observation. A large area of roof damage, due to wind displacement occurred in the upwind south end of the building. The membrane system, including the base layer, was detached from the LWIC. Most LWIC remained attached to the steel deck. Some reglets pulled out of the wall in downwind areas. Many of the plastic drain strainers had come loose and blown to the far side of the roof and collected in a corner. Debris created some impact damage on the far side of the parapet. A small pyramidal roof on this roof section, with a metal roof covering, sustained hip/ridge trim displacement.

DAMAGE INITIATION—The damage occurred from the south end, southeast corner, adjacent to the parapet wall. This observation is based on the damage on other buildings at the site that sustained the most damage on the similar south–southeast position. The detached membrane exhibited both fastener pullout from the LWIC deck (fasteners still intact within the membrane) and some fasteners tearing through the base layer in the membrane. The lift forces, whether from uplift or from pressurization, exceeded the fastening pattern density resistance.

COMMENTS—Generally, LWIC type decks are considered to be relatively less air-permeable compared with other deck systems, depending on what is done at penetrations and perimeters. The fastening pattern on the installation of the base sheet was inconsistent and did not appear to have enhanced perimeter fastening; and while small plates were used, no large plates for greater tear-through resistance were observed. Similar to some other building damage observed during this trip, there were louver openings in the wall below the membrane damage area. The louver openings and other points of air entry would be a design consideration for determining if those sections of the building would be considered enclosed or partially enclosed and pressures accommodated.

2.10 U.S. Post Office, 101 S. Palafox

TYPE OF STRUCTURE—Post office

EXPOSURE—B

WALL CONSTRUCTION—Wood frame, stucco

ROOF SYSTEM—BUR smooth surface coated

ROOF SLOPE—1–2":12"

ROOF DECK—Wood plank

WIND SPEED—110–120 mph

COORDINATES—N30°24.692′—W87°12.903′

CONSTRUCTION—Wood frame with wood plank deck, stucco exterior. Roof height is about 24 ft. with a 3-ft. parapet sloped to the back at 19 ft. Surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with no surface roughness in grade; but there are taller buildings to the south and east. The building is in downtown Pensacola with the front of the building facing east. This building is lower in elevation than some surrounding buildings. Taller buildings surrounding this location had substantial membrane loss and loss of cornice and marquee attachment structures.

ROOF MEMBRANE SYSTEM—Mechanically attached 3-ply BUR with white reflective coating over a wood plank deck.

NOTED DAMAGE—There was a report of broken windows, and we noted displacement of the front (east) cornice metal roof cover. The south section of the main roof covering had a tear along the upwind (east) parapet wall. Both sections of roof apparently lifted off the deck, pulled fasteners from the wood deck, and then laid back into place. Base ply fastener nails that had lifted with the membrane penetrated up through the membrane in several areas.

DAMAGE INITIATION—It is clear from the torn portion of the membrane/parapet covering that it separated from the structure at some point in the storm on the east end, based on the large tear in the membrane on the east-side parapet. Based on the lifting and re-laying of the membrane, there was membrane detachment over halfway down the deck slope

COMMENTS—This is a storefront post office in downtown Pensacola. The building was temporarily made watertight with roof cement mastic at the tears, but the roof was seriously damaged and could leak or be displaced in a future storm. Air permeation in buildings and through decks can provide a mechanism for positive pressurization below the deck and subsequent lifting of the roof covering.

2.11 U.S. Post Office, 5200 Lillian Hwy, Myrtle Grove (West Pensacola)

TYPE OF STRUCTURE—Post office

EXPOSURE—B

WALL CONSTRUCTION—CMU block with parge or stucco coating

ROOF SYSTEM—BUR with modified bitumen cap sheet

ROOF SLOPE—¼–½":12"

ROOF DECK—Steel

WIND SPEED—110–120 mph

COORDINATES—N30°23.843′—W87°17.240′

CONSTRUCTION—CMU walls with parge or stucco system resurfacing. Roof height is 18 ft.; roof deck is steel. Surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with no surface roughness in grade but surrounding tall trees. This building is one story.

ROOF MEMBRANE—BUR with modified bitumen granular cap sheet over isocyanurate insulation. This building had been re-roofed within the last 6 months.

NOTED DAMAGE—This roof was undamaged. There was damage to the canopy overhang soffit panels on the west side, originating from the south end.

COMMENTS—This building was lower than the surrounding trees. The roof was relatively new. On the loading dock canopy on the westward wall, there was some “blow-out” displacement of select pieces of the soffit closure metal—it was not widespread.

2.12 Escambia County School District, J. E. Hall Educational Services Center, 30 E. Texar Dr.

TYPE OF STRUCTURE—School building

EXPOSURE—B

WALL CONSTRUCTION—Cast-in-place concrete with brick facade

ROOF SYSTEM—BUR

ROOF SLOPE—¼":12"

ROOF DECK—Precast concrete T-panels

WIND SPEED—110–120 mph

COORDINATES—N30°26.774′—W87°13.379′

CONSTRUCTION—One-story school building (formerly Booker T. Washington High School) now converted to other uses. The building is a cast-in-place concrete structure with brick facade and three tiered or terraced roof levels plus a walkway canopy. The terraced roof elevations face either the south and/or east edges. The roof deck is a precast concrete T-panel that extends over the bearing walls to create an unenclosed 34-in. overhang. The T-panel joints were not sealed. The building height is 16 ft. to the roof. Surrounding terrain would qualify as Exposure B according to ASCE 7-02 with no surface roughness in grade, but there are buildings roughly equal in height to the south and east and one 3-story (+) building to the southeast. The site is located in the southern portion of Pensacola, inland a few miles, straight north of the Pensacola Bay inlet.

ROOF MEMBRANE—BUR roof, smooth surfaced, on 1½-in. perlite insulation mopped to the deck.

NOTED DAMAGE—Windows had been damaged on the south and east sides. More than 60% of the roof was displaced and repaired. Damage occurred on all three tiers, occurring on the south/east portions. The gravel stop fascia was missing in most of the upwind east and south area, and portions of the gravel stop wood nailer were also missing. The perimeter edge wood nailers showed signs of deterioration.

DAMAGE INITIATION—The tiered roofs (but not the canopy cover) had damage at the south and east upwind, leading edges originating in the southeast corners. The roof covering displacement diminished part way downwind and across the roofs. The roof system could have been pressurized from below the T-panel joints from the interior and on the overhangs as well as at the gravel stop edges.

COMMENTS—The damaged windows and openings in the T-panels on the south and east sides provided the opportunity for interior pressurization. The loss of the gravel stop and some perimeter nailers, if they were lost first, could also provide for positive pressurization under the membrane. This was one in a group of about 20 buildings with similar structure and roofs. Several, but not all, had similar roof membrane displacement, typically from the southeast/east sides, including a 3-story metal roof covering with panel displacement and damage loss initiating from the south/southeast.

2.13 Escambia County School District, J. E. Hall Educational Services Center, 30 E. Texar Dr. (rear section of roof)

TYPE OF STRUCTURE—School building

EXPOSURE—B

WALL CONSTRUCTION—Cast-in-place concrete with brick facade

ROOF SYSTEM—Granular surface modified bitumen

ROOF SLOPE—¼":12"

ROOF DECK—Concrete

WIND SPEED—110–120 mph

COORDINATES—N30°29.260′—W87°10.680′

CONSTRUCTION—One-story school building, now converted to other uses. The building is a cast-in-place concrete structure with brick façade. The roof is at the same elevation as the roof in report 2.12 but downwind (west). The roof deck is a precast concrete T-panel that extends over the bearing walls to create an unenclosed 34-in. overhang. The T-panel joints were not sealed. The building height is 16 ft. to the roof. Surrounding terrain would qualify as Exposure B according to ASCE 7-02 with no surface roughness in grade, but there are buildings roughly equal in height to the south and east and one 3-story+ building to the southeast.

ROOF MEMBRANE—This appears to be a granular surfaced modified bitumen sheet over insulation.

NOTED DAMAGE—None to roof covering system. However, there was the displacement loss of exhaust fan top covers on multiple devices, exhibiting enlarged fastener holes in the sheet metal fan shroud that is remaining.

COMMENTS—This was a divided roof area but a separate roof section, downwind of the roof from report 2.12. It had been recently re-roofed and sustained no roof covering system damage. Although this section had the same overhangs, and some windows broken from below like the roof in report 2.12, it was further to the downwind, leeward end of the building and may not have been exposed to as high a wind pressure.

2.14 Escambia County School District, J. E. Hall Educational Services Center, 30 E. Texar Dr. (directly behind old gymnasium)

TYPE OF STRUCTURE—School building

EXPOSURE—B

WALL CONSTRUCTION—Cast-in-place concrete with brick facade

ROOF SYSTEM—PVC

ROOF SLOPE—¼":12"

ROOF DECK—Cast-in-place concrete

WIND SPEED—110–120 mph

CONSTRUCTION—One-story school building, now converted to other uses. Cast-in-place concrete building with brick facade. The roof deck is believed to be cast-in-place concrete with a building height of 16 ft. to the roof. There are two roof sections on this building—the northernmost section slightly elevated by less than 2 ft above—and an 18-in. parapet on the upwind and downwind sides. Surrounding terrain would qualify as Exposure B according to ASCE 7-02, with no surface roughness in grade; but the 3-story (+) gymnasium building is directly to the south, and there are other buildings roughly equal in height to the north and west.

ROOF MEMBRANE—Reinforced, fleece-backed PVC elastomeric single-ply sheet, adhered to insulation. System had one termination bar approximately 3 ft. in from perimeters—installed over the membrane and then patched over, creating a compression device within the membrane. The east and west elevations mostly have an eave edge detail on the southern roof section and a short parapet detail on the northern roof section. The system age is not known.

NOTED DAMAGE—One or two drain strainer covers were displaced.

DAMAGE INITIATION—Strainer covers not tightened into clamp rings.

COMMENTS—This roof may have been afforded some protection from the adjacent gymnasium to the south when the wind was from the south. Insulation softness under foot pressure was noted at the south end, possibly indicating some lift or shifting of boards under the membrane; but it was not visually obvious. The building is in the same complex where many older BUR roofs had been damaged by the wind (see reports 2.12 and 2.13). The system has some fastening enhancement, such as the one row of perimeter edge termination bars and fasteners at penetrations that would be expected to minimize air infiltration and migration under the membrane.

2.15 Scenic Heights Elementary School, Langly Dr. at Hibiscus

TYPE OF STRUCTURE—School

EXPOSURE—B

WALL CONSTRUCTION—Brick clad and windows

ROOF SYSTEM—PVC

ROOF SLOPE—¼":12"

ROOF DECK—LWIC on cementitious wood fiber panels

WIND SPEED—110–120 mph

CONSTRUCTION—The building walls are clad with brick and window sections; the wall is believed to be of masonry construction. One-story 16-ft. building. The roof deck is cementitious wood fiber deck panels covered with LWIC. The roof deck is supported by concrete beams that protrude past the wall lines, creating open overhang sections. There are many windows, some protected by storm shutters. Surrounding terrain would qualify as Exposure B, according to ASCE 7-02, with no surface roughness at grade but there are surrounding tall trees on all sides.

ROOF MEMBRANE—Fleece-backed PVC adhered to LWIC.

NOTED DAMAGE—One small portion of this roof section was damaged by two trees falling, in different directions but in close proximity, onto the roof. There were about three punctures at one tree location and three at the other location from branches. There was also some deck damage at the overhangs; two locations exhibited fracturing and vertical depression as a result of impact.

DAMAGE INITIATION—Trees falling

COMMENTS—Off to the side of the roof observed, there were two other similar roof sections. One of them also had one tree branch puncture; the other section had no observed damage. Also, a window with storm shutters, facing east on one building, was severely pocked (but not broken or cracked) by stones or other wind-borne debris.

The site also had an open structure, with a steel tube frame and steel purlin supports covered with an aluminum standing seam roof, covering a walkway that extended north and south on the east side of the site for student pick-up. The roof was a shed-style configuration (mono-slope) with the highest elevation “open ridge” facing east at the car pick up side. The roof had significant panel displacement and damage to some remaining panels, with the propagation apparently from the southeast by the storm. Other metal roofs on structures at the site lost some ridge trim metal.

Photographs of Roof Damage

West Florida Hospital Ancillary Building

2-01-1. Damage to roof by debris from wall above roof.

2-01-2. Well-attached coping.

West Florida Hospital—East Patient Hospital

2-02-1. Overview of ballasted roof.

2-02-2. Gravel scour in corner.

2-02-3. Stone size of gravel.

Tower Medical Building

2-03-1. Tower Medical Building overview.

2-03-2. Looking northeast: missing coping.

2-03-3. Patches on the roof.

Baptist Hospital Main Building

2-04-1. Partial overview of hospital main building.

2-04-2. Tower roof with anemometer.

2-04-3 Temporary repairs over stairwell; note vents.

Baptist Hospital Medical Facility, T-3 Penthouse Roof

2-06-1. Tower roof.

2-06-2. Inside penthouse; light is from open areas on hips of metal roof.

Medical Office Building, Sacred Heart Hospital Complex

2-07-1. Repaired tear.

2-07-2. Debonded membrane.

Main Hospital, Sacred Heart Hospital

2-08-1. Overview of graveled roof.

2-08-2. Edge metal missing from penthouse.

DePaul Building, Sacred Heart Hospital

2-09-1. Blow-off area.

2-09-2. Base layer fastening pattern.

2-09-3. Vent and cladding failure below blow-off.

U.S. Post Office, Pensacola

2-10-1. Membrane tear due to detachment.

Escambia County School District, J. E. Hall Educational Services Center

2-12-1. Missing flashing from upper roof.

U.S. Post Office, Myrtle Grove

2-11-1. Undamaged roof.

2-12-2. Note large repaired area on this and adjacent roof.

2-11-2. Soffit damage.

2-12-3. Missing windows and missing edge metal.

Escambia County School District, J. E. Hall Educational Services Center

2-14-1. Missing drain covers directly behind old gymnasium.

2-14-2. Directly behind old gymnasium.

2-14-3. Perimeter metal behind old gymnasium.

Scenic Heights Elementary School

2-15-1. LWIC on cementitious wood fiber deck.

2-15-2. Debris damage caused by tree.

2-15-3. Minor damage caused by tree debris and damage to metal roof.

Scenic Heights Elementary School (cont.)

2-15-4. Walkway roof with displacement.

2-15-5. Metal-covered walkway.

2-15-6. Missing hip and ridge.

HURRICANE IVAN: TEAM 4

OVERVIEW

Team 4 focused on low slope roof coverings on schools and essential facilities around the greater Pensacola, Florida, area. The team observed 14 roofs at 5 different sites, documenting roof construction, wind damage conditions, and likely initiation points of the wind damage. Figure 1 shows the approximate locations of the five sites. All 14 roofs were on low-rise buildings (less than 60 ft. high) in Exposure B. Seven of the 14 roofs had single-ply roof coverings, and 7 had built-up roof (BUR) and/or modified bitumen (MB) roof coverings. The roofs included loose-laid and ballasted, fully adhered, and mechanically attached membranes. Roof decks included concrete, steel, wood fiber cement, and lightweight insulating concrete (LWIC). Where existing roof coverings appeared to be watertight, information gathering on roof construction and damage conditions was limited to information that could be obtained short of making observation openings in the roof coverings.

Team 4 Members

Phil Dregger, Report Writer, Photographer
Jason Smart, Data Recorder, Sample Collector
Ron Kough, Data Recorder, Sample Collector
Mike Gada, Data Recorder, Sample Collector

Figure 1. Approximate locations (red circles) of the five sites investigated by Team 4.

SUMMARY OBSERVATIONS

Wind-related damage conditions observed on the 14 roofs ranged from minor to extensive. Damage conditions included loss of edge metal; punctures/tears in roof membranes; withdrawal and pull-over of securement fasteners; and at some locations, complete displacement (blow-off) of the roof system.

The 14 roofs exhibited some commonality in where wind damage began, how damage progressed, and what conditions damage was associated with. Events believed associated with initiation of wind damage included the following:

- Lifting of edge metal (cleat deformation and flashing disengagement)
- Billowing of membranes and membrane base flashings (air infiltration into spaces behind base flashings and below roof membranes)
- Puncturing/tearing of the roof membrane from wind-borne debris and wind-toppled equipment
- Release of deck panels from attachment points

Scenarios of how wind damage progressed from initiation points included the following:

- Membranes billowed, fasteners holding termination bars and sheathing boards pulled out and/or through, ballast (if present) was displaced by billowed membrane, sheathing boards and/or base flashings were displaced, and then the roof membrane tore around fasteners and peeled back.
- Edge cleats deformed, edge metal bent upward, edge metal and/or nailers lifted, and then the roof membrane tore around fasteners and peeled back.
- Debris punctured membrane, wind billowed membrane near puncture, and membrane tore (mechanically attached single-ply roofs only).

Conditions most often associated with damage observations included

- Deteriorated roof attachment systems (resulting in a reduced wind uplift resistance)
  - — Corroded fasteners/hardware
  - — Deteriorated wood substrates
  - — Deteriorated mechanically attached base sheets
- Roof constructions that varied from common industry recommendations
  - — No increase of mechanical attachment in perimeters or corners to compensate for increased loads as specified in ASCE 7 or FM-1-29
  - — Edge metal cleat gauges and wood nailer securements less than recommended in FM Global LPDS 1-49 (1979) and ANSI/SPRI ES-1 (adopted in 2003 IBC)
- Roof constructions that included openings that allowed rapid air infiltration between roof membranes and roof decks
- Locations exposed to wind-borne debris

Suggestions to enhance wind resistance of roof coverings, based on Team 4 observations, include these:

- Design/construct roof coverings in accordance with available high-wind design guidelines (e.g., ASCE-7, ANSI/SPRI ES-1, RP-4, FM Global LPDS) and roof materials manufacturers' instructions.
- Use conservatively durable materials as part of roof attachment systems (e.g., stainless steel fasteners, preservative-treated wood) where the possibility exists of exposure of these elements to long-term moisture conditions.
- Design/construct roof coverings to limit air flow between roof coverings and roof decks.

INDIVIDUAL ROOF REPORTS

The following are narrative summaries of observations and findings for each roof observed. Photographs appear at the end of the summaries.

4.01 Field House, 11000 University Parkway

ROOF SYSTEM—MB

WIND SPEED—110–120 mph

CONSTRUCTION—Low-rise, steel-frame school building in Exposure B with concrete masonry unit (CMU)/brick exterior walls and very few openings. The roof assembly, installed about 1998, consists of 2-ply MB with a G2-type base sheet mechanically attached to LWIC over a steel form deck. The roof is surrounded by 24-in.-high perimeter curbs covered with metal copings. A steeply sloped metal roof covering is positioned along one side.

NOTED DAMAGE—Wind-related damage was limited to several punctures through the MB membrane.

DAMAGE INITIATION AND PROPAGATION—Winds removed large portions of the adjacent metal roof. Some of these windborne metal roof panels struck the MB roof covering and punctured it. The wind damage conditions did not propagate.

4.02 Field House, 11000 University Parkway

ROOF SYSTEM—Single-ply roof covering near windward corner

WIND SPEED—110–120 mph

CONSTRUCTION—Low-rise, steel-frame school building in Exposure B with CMU/brick exterior walls and very few openings. The roof assembly, installed about 2000, consists of a reinforced polyvinyl chloride (PVC) membrane mechanically attached through isocyanurate insulation into a steel deck. Membrane fastening increased along wind-exposed perimeters. The roof is surrounded by 18-in.-high perimeter curbs covered with metal copings.

NOTED DAMAGE—Membrane remained intact. Insulation, and possibly also steel deck, lifted in a 100–150 ft^2 area near a windward corner.

DAMAGE INITIATION AND PROPAGATION—Inconclusive

4.03 Field House, 11000 University Parkway

ROOF SYSTEM—Single-ply roof covering near metal roof

WIND SPEED—110–120 mph

CONSTRUCTION—Low-rise, steel-frame school building in Exposure B with CMU/brick exterior walls and very few openings. The roof assembly, installed about 2000, consists of reinforced PVC membrane mechanically attached through isocyanurate insulation into steel deck. Membrane fastening increased along wind-exposed perimeters. The roof is surrounded by 18-in.-high perimeter curbs covered with metal copings. A steeply sloped metal roof covering is positioned along one side.

NOTED DAMAGE—The PVC membrane has several punctures. Most punctures include gouges in the insulation and tears in the membrane. One tear was more than 6 ft. long.

DAMAGE INITIATION AND PROPAGATION—Winds toppled one platform-mounted roof-top unit and displaced large portions of the adjacent metal roof (see Ivan Team 5 report, Building 5.09).

The toppled piece of equipment and some of the airborne metal roof panels struck the PVC membrane and punctured it. Tears in the PVC membrane propagated from the punctures.

COMMENTS – The roof-top unit appeared to be resting on the platform without any means of mechanical securement.

4.04 Pool Building, 11000 University Parkway

ROOF SYSTEM—Ballasted single-ply

WIND SPEED—110–120 mph

CONSTRUCTION—Low-rise, steel-frame pool building in Exposure B with metal wall cladding and many glazed openings. Roof assembly, installed about 1984, consists of unreinforced PVC membrane loose-laid and ballasted (nominal 2 in. stone) over isocyanurate insulation and wood fiber cement deck panels. The roof has one higher and one lower roof section, has six large sawtooth-shaped skylights, and is surrounded by 28-in.-high parapet walls (steel stud and plywood construction) covered with metal copings. Metal copings do not have cleats but are attached with screws through both vertical sides. Roof membrane wall coverings were adhered to parapet sheathing. A mansard-like steeply sloped metal roof is positioned adjacent to and immediately below the higher roof section.

NOTED DAMAGE—Copings, parapet wall coverings, parapet sheathing, roof insulation, and PVC roof membrane billowed, displaced, and torn near corner of higher roof section. No visible damage over lower roof sections. Wood fiber cement deck remained in place. One glazed opening was broken below the lower ballasted roof section. Winds removed a large section of the metal roof adjacent to the higher roof section.

DAMAGE INITIATION AND PROPAGATION—Air infiltration from two sources below roof membrane at the windward corner initiated wind damage. One source—wind displacement of the adjacent metal roof covering—left the backside of the interior parapet sheathing exposed to direct positive pressure. Another source—interior air—infiltrated up the exterior wall and through openings in the deck, to the underside of the membrane. Parapet sheathing and the membrane termination bar separated from their substrates. Membrane billowed, pulled off copings, and tore around fasteners.

COMMENTS—Sheathing and sheathing fasteners near windward corner were moderately deteriorated/corroded. The deterioration/corrosion conditions resulted in a reduced level of wind uplift resistance compared with non-deteriorated/corroded conditions. Infiltration and condensation of moisture- (and possibly also chlorine-) laden interior air is suspected as the fuel for deterioration/corrosion conditions.

4.05 Pool Building, 11000 University Parkway

ROOF SYSTEM—Mechanically attached single-ply

WIND SPEED—110–120 mph

CONSTRUCTION—Low-rise, steel-frame pool building in Exposure B with metal wall cladding and many glazed openings. Roof assembly, installed about 1984, consists of reinforced PVC membrane mechanically attached through isocyanurate insulation into nominal ½-in. oriented strand board (OSB) sheathing over wood fiber cement deck panels. Roof is sloped at about 6":12" and positioned between two ballasted roof sections. (See Sect. 4.04.) The roof is surrounded on two sides by 28-in.-high parapet walls (steel stud and plywood construction) covered with metal copings. Metal copings do not have cleats but are attached with screws through both vertical sides. Roof membrane wall coverings were adhered to parapet sheathing.

NOTED DAMAGE—Copings, parapet wall coverings, parapet sheathing, roof insulation, and PVC roof membrane were displaced over the eastern half of the roof section. OSB sheathing and exterior metal wall cladding remained in place. One glazed opening was broken below adjacent ballasted roof section.

DAMAGE INITIATION AND PROPAGATION—Interior air infiltrated up exterior wall and through openings in deck to underside of membrane. Parapet sheathing and the membrane termination bar separated from their respective substrates. Membrane billowed, pulled off copings, and tore around membrane fasteners. Roof insulation mostly stayed in place.

COMMENTS—Sheathing and sheathing fasteners near where damage initiated had advanced levels of deterioration/corrosion. The deterioration/corrosion conditions resulted in a reduced level of wind uplift resistance compared with non-deteriorated/non-corroded conditions. Infiltration and condensation of moisture- (and possibly also chlorine-) laden interior air suspected as fuel for deterioration/corrosion conditions.

4.06 Emergency Operations Center, L Street and St. Mary's

ROOF SYSTEM—MB (newer one of two)

WIND SPEED—110–120 mph

CONSTRUCTION—The EOC is a 35-ft.-tall, steel-frame structure in Exposure B with stucco-clad CMU exterior walls and several glazed openings. The roof assembly consists of a MB membrane mechanically attached into LWIC over a steel form deck. The LWIC/steel deck is separated by about ½ in. from the exterior CMU walls. The roof is surrounded by 12-in.-high perimeter curbs (CMU) covered with metal copings. Metal copings are attached with clips 5 ft. on center (o.c.).

NOTED DAMAGE—The MB membrane lifted from the LWIC substrate in a large area along one side but remained mostly intact. Copings deformed and twisted but remained on top of the perimeter curbs. Although torn on the interior side, base flashings remained adhered to the top of the perimeter curbs. The MB membrane tore along the base flashings and around one drain in the lifted area. No glazing was broken.

DAMAGE INITIATION AND PROPAGATION—Interior air infiltrated up the east exterior wall through gaps between the CMU and the LWIC/steel deck to the canted MB base flashings. The MB membrane billowed, pulling fasteners from the LWIC deck (perhaps pulling the base sheet over the fasteners), tearing base flashings, and tearing the membrane around one drain.

COMMENTS—Temporary repairs limited observations of construction and damage conditions.

4.07 Emergency Operations Center, L Street and St. Mary's

ROOF SYSTEM—MB (older one of two)

WIND SPEED—110–120 mph

CONSTRUCTION—The EOC is a 35-ft.-tall, steel-framed structure in Exposure B with pre-cast concrete panels covering exterior walls. The structure has some overhangs and several glazed openings. The roof assembly consists of a MB membrane mechanically attached to LWIC over structural concrete. The G2-type base sheet was attached with 1.7-in.- long expanding wedge fasteners with 1- to 1.25-in.-diameter heads, 9 in. o.c. along laps and 24-in. o.c. in two rows staggered between laps. No additional fasteners were installed in roof perimeter or corner areas. The roof is surrounded by 12-in.-high perimeter curbs (pre-cast concrete panels) partially covered with metal copings. The metal copings terminate at horizontal reglets on the top of the short curbs. A concrete heliport pad in the center of this roof section is covered with the same MB membrane but over perlite insulation instead of LWIC.

NOTED DAMAGE—The MB membrane lifted from the LWIC substrate and peeled back over virtually the entire roof area. Copings, some base flashings, and the LWIC remained intact. Nearly all the base sheet fasteners remained in the LWIC substrate. No glazing was broken.

DAMAGE INITIATION AND PROPAGATION—Winds confined by an overhang on the windward side created high pressure below the overhang. This high-pressure air infiltrated up under the roof membrane through unsealed or partially sealed joints between the pre-cast exterior wall panels. The MB membrane billowed, pulling the base sheet over the heads of the base sheet fasteners (see Comments below), tearing base flashings, and peeling back the roof membrane.

COMMENTS—The G2-type base sheet was very deteriorated and brittle. Deterioration is suspected to be related to long-term exposure of ply sheet reinforcements and binders to high temperatures and/or moisture in a highly alkaline environment.

Base sheet fastening pattern was less than is typically recommended by roof material manufacturers.

An aggregate-surface BUR, positioned immediately to the north and at the same elevation as this roof and the roof described in Section 4.06, had no visible wind damage.

The current roof covering was not the original roof covering. At least one other roof had been installed and removed prior to installation of the current roof covering.

4.08 School Campus, PE Building, 6299 Lanier

ROOF SYSTEM—Combination MB and BUR

WIND SPEED—110–120 mph

CONSTRUCTION—The PE Building is a 16 ft.-tall, concrete frame structure in Exposure B with CMU/brick exterior walls constructed about 1999. The roof has overhangs and many glazed openings. The roof assembly consists of a MB/BUR membrane adhered with hot asphalt to isocyanurate insulation, adhered with hot asphalt to a base sheet mechanically attached to the wood fiber cement plank deck. The G2-type base sheet was attached with 1½-in.-long locking wedge fasteners with 1-in.-diameter heads installed 16 in. along laps and in two rows 18 in. o.c. staggered between laps. No additional fasteners were installed in roof perimeter or corner areas. The perimeter edge consists of flanged edge metal (0.032-in. aluminum) with a continuous cleat (0.032-in. aluminum) secured to wood nailers secured with screws to the wood fiber cement deck. The wood fiber cement planks are secured to the precast beams by heavy-gauge galvanized clips that engage steel reglets cast into the precast beams.

NOTED DAMAGE—About 50% of the roof edge metal, nailers, insulation, and base sheet were displaced. The wood fiber cement planks were displaced from supports along the windward overhangs. About half of the base sheet fasteners remained in the wood fiber cement deck and half were removed. No glazing was broken.

DAMAGE INITIATION AND PROPAGATION—There were three different damage modes acting simultaneously or in quick succession. Winds confined by the overhangs on the windward sides created high pressure below the overhangs. The high-pressure air infiltrated up between the wood fiber cement planks, lifting the roof system and pulling some base sheet fasteners from the deck. The cleat holding the roof edge metal deformed, releasing the roof edge metal to bend upward and back. These two damage modes lifted the nailers from the deck and tore the base sheet around the remaining base sheet fasteners, allowing the roof covering to peel up and backward. Then the wood fiber cement planks on the overhangs pulled the plank clips from the embedded reglets.

COMMENTS—The embedded steel reglets holding the wood fiber cement clips had advanced deterioration (up to 50% loss of section), resulting in a reduced wind uplift resistance of the roof assembly compared with non-deteriorated conditions. The screws securing the wood nailers to the wood fiber cement had advanced deterioration (up to 30% loss of section), resulting in a reduced wind uplift resistance of the roof assembly compared with non-deteriorated conditions. The 0.032-in. aluminum roof edge metal is less than the minimum 0.040-in. aluminum currently recommended in FM Global Loss Prevention Data Sheet 1-49. The 0.032-in. aluminum cleat is less than the minimum 0.050-in. aluminum currently recommended in FM Global Loss Prevention Data Sheet 1-49.

4.09 School Campus, West Annex, 6299 Lanier

ROOF SYSTEM—Cap sheet surfaced BUR

WIND SPEED—110–120 mph

CONSTRUCTION—The West Annex is a 24-ft.-tall concrete frame structure in Exposure B with CMU/brick exterior walls. The roof has overhangs and several glazed openings. The roof assembly consists of a cap sheet surfaced BUR membrane adhered with hot asphalt to perlite insulation, adhered with hot asphalt to a concrete deck. The perimeter edge consists of flanged edge metal (0.032-in. aluminum) with a 6-in. vertical side but no cleat. The flange is secured to wood nailers that in turn are secured to the concrete deck.

NOTED DAMAGE—About 70% of the roof edge metal and insulation was displaced. The insulation and nailers remained in place. No glazing was broken.

DAMAGE INITIATION AND PROPAGATION—Without a cleat, the vertical portions of the roof edge metal readily bent upward and initiated peeling of the roof membrane from the perlite insulation.

COMMENTS—Not having a cleat on a 6-in. vertical side of edge metal varies from current recommendations in FM Global Loss Prevention Data Sheet 1-49. The 0.032-in. aluminum roof edge metal is less than the minimum 0.040-in. aluminum currently recommended in FM Global Loss Prevention Data Sheet 1-49.

4.10 School Campus, Clinic/NW Building, 6299 Lanier

ROOF SYSTEM—PVC single-ply

WIND SPEED—110–120 mph

CONSTRUCTION—The Clinic/NW Building is a 16-ft.-tall, steel frame structure in Exposure B with CMU/brick exterior walls and limited openings. The roof assembly consists of a reinforced PVC membrane mechanically attached through insulation of unknown type into a steel deck. Membrane fastening increases in perimeter areas to about one fastener every 2.8 ft^2. The roof is surrounded on three sides by 24-in.-high parapets covered by metal copings. The fourth side is a flush roof edge with a hanging gutter. The hanging gutter is secured with spacers (straps) 36 in. o.c. but no brackets.

NOTED DAMAGE—Eighteen feet of the hanging gutter and some vent covers were displaced. No damage was observed on the PVC roof covering.

DAMAGE INITIATION AND PROPAGATION—The hanging gutter (secured only along the top edge) rotated up and outward, pulled out the screws holding the straps, and fell.

COMMENTS—The *Architectural and Sheet Metal Manual* published by the Sheet Metal and Air Conditioning Contractors' National Association recommends spacers (straps) 36 in. o.c. and brackets (holding the bottom of the gutter) 36 in. o.c.

4.11 School Campus, Building 1, 2600 Longleaf

ROOF SYSTEM—Ethylene propylene diene monomer (EPDM) single-ply (overlay)

WIND SPEED—110–120 mph

CONSTRUCTION—Building 1 is a 16-ft.-tall, steel-frame structure in Exposure B with brick/stucco–clad exterior walls and many glazed openings. The roof assembly consists of a 60-mil EPDM membrane fully adhered to 1-in. isocyanurate insulation mechanically attached (coated fasteners, one fastener per 2 ft^2) through an older MB membrane and LWIC into a steel form deck. No additional insulation fasteners were installed in roof perimeter or corner areas. The perimeter edge consists of flanged edge metal (0.032-in.aluminum) with a continuous cleat (0.032-in. aluminum) secured 5 in. o.c. to wood nailers. The EPDM membrane was installed under the flanged edge metal and over (not behind) the continuous cleat.

DAMAGE CONDITIONS –Most of the EPDM membrane and much of the rigid board insulation were displaced by winds. Most of the older MB membrane remained in place. No glazing was broken.

DAMAGE INITIATION AND PROPAGATION—The cleat holding the roof edge metal deformed, releasing the roof edge metal to bend upward and back. The roof edge metal and EPDM membrane peeled the fiberglass facer from the insulation. The insulation boards severed the fastener shafts or fractured the plastic fastener plates and lifted off the deck.

COMMENTS—Fasteners securing both the roof edge metal and the isocyanurate insulation had advanced deterioration (up to 90% loss of section), resulting in reduced wind uplift resistance of the roof assembly compared with non-deteriorated conditions. The 0.032-in. aluminum roof edge metal is less than the minimum 0.040-in. aluminum currently recommended in FM Global Loss Prevention Data Sheet 1-49. The 0.032-in. aluminum cleat is less than the minimum 0.050-in. aluminum currently recommended in FM Global Loss Prevention Data Sheet 1-49. Currently, most EPDM roof membrane manufacturers recommend installing the field membrane over the outside edge and behind (not over) the continuous cleat. A configuration with the field membrane over the cleat would be expected to provide less resistance to membrane peel along the roof edge, compared with a configuration with the membrane installed behind the cleat.

4.12 School Campus, Building 2, 2600 Longleaf

ROOF SYSTEM—Thermoplastic olefin (TPO) single-ply

WIND SPEED—110–120 mph

CONSTRUCTION—Building 2 is a 16-ft.-tall steel-frame structure in Exposure B with brick/stucco–clad exterior walls and many glazed openings. The roof assembly consists of a TPO membrane fully adhered to an unknown type of insulation into a steel deck. The perimeter edge is flush and consists of flanged edge metal (2-in. vertical side, no cleat) and a hanging gutter with spacers 24 in. o.c. but no brackets.

NOTED DAMAGE—One puncture in the roof membrane

DAMAGE INITIATION AND PROPAGATION—Wind-borne debris from the adjacent wind damaged roof on Building 1 struck and punctured the roof membrane.

4.13 School Campus, Main Building, 2500 Longleaf

ROOF SYSTEM—MB

WIND SPEED—110–120 mph

CONSTRUCTION—The Main Building has a large lower roof area and a smaller upper roof area. The upper roof was the focus of Team 4 observations. The upper roof is on a 39-ft.-tall, steel-frame structure in Exposure B with CMU exterior walls and limited openings. The roof assembly consists of a 2-ply MB membrane over a base sheet mechanically attached with 3-in.-diameter plates and screws through loose-laid isocyanurate insulation into a steel deck. The base sheet fastening pattern was 15 in. o.c. along laps and two rows, not staggered, 15 in. o.c. between laps. There was no increase in fastener density in perimeter or corner areas. The perimeter edge has two configurations. Where there is a hanging gutter, the perimeter edge consists of flanged edge metal (0.032-in. aluminum, no cleat) secured 6 in. o.c. to wood nailers. Where the roof adjoins a metal roof, the perimeter edge also consists of flanged metal; but this same metal serves to counterflash the upper end of the metal roof. The perimeter wood nailers consisted of multiple pieces of wood of different thicknesses, some installed on edge.

NOTED DAMAGE—The roof edge metal and roof membrane were displaced by wind over about 40% of the upper roof. A few pieces of the underlying insulation were also displaced.

DAMAGE INITIATION AND PROPAGATION—There were at least two different damage modes acting simultaneously or in quick succession. The windward roof edge metal (no cleat) bent upward and pulled the flange from the wood nailers and/or lifted portions of the wood nailers from the deck. In addition, the metal edge flashings (also serving as counterflashings for the adjacent metal roof covering) bent upward as the metal roof panels were displaced by winds. These damage modes acted together to tear the base sheet around the insulation fasteners and allowed the roof membrane to be peeled backward off the rigid board insulation.

COMMENTS—Winds entering a louvered vent in the windward wall probably pressurized the space below the roof deck and incrementally increased the wind uplift pressures transferred to the roof covering. The configuration and securement of wood nailers varied from current recommendations in FM Global Loss Prevention Data Sheet 1-49. Roof edge flange securement of 6 in. o.c. is more than the 3–4 in. o.c. currently recommended by most roof materials manufacturers. The 0.032-in. aluminum roof edge metal is less than the minimum 0.040-in. aluminum currently recommended in FM Global Loss Prevention Data Sheet 1-49.

4.14 School Campus, Building 1, 4425 Bellview

ROOF SYSTEM—PVC single-ply (overlay)

WIND SPEED—110–120 mph

CONSTRUCTION—Building 1 is an 18-ft.-tall, concrete frame structure in Exposure B with brick exterior walls and many glazed openings. The roof assembly consists of, from top to bottom, a fleece-backed PVC (recover membrane) fully adhered to an older aluminum-coated, smooth-surfaced BUR membrane, adhered with hot asphalt to composite perlite/isocyanurate and wood fiber insulation, adhered to a concrete deck. The roof has overhangs and a flush roof edge. The perimeter edge consists of flanged edge metal (0.032-in. aluminum) secured 3 in. o.c. to wood nailers, and clips (0.032-in. aluminum) 30 in. o.c. The roof edge metal appears to be part of the BUR installation, not part of the more recent PVC recover membrane.

NOTED DAMAGE—The PVC recover membrane, as well as the older BUR membrane, were displaced by winds over an entire corner of the roof. Some nailers and some insulation were also displaced.

DAMAGE INITIATION AND PROPAGATION—The clips of the windward roof edge metal deformed, releasing the roof edge metal to bend upward. The roof edge metal pulled the smooth-shank nails from the wood nailers and initiated peel of the PVC/BUR membrane from the rigid board insulation.

COMMENTS—The use of discrete clips 30 in. o.c. varies from the current recommendation to use continuous cleats in FM Global Loss Prevention Data Sheet 1-49. The 0.032-in. aluminum roof edge metal is less than the minimum 0.040-in. aluminum currently recommended in FM Global Loss Prevention Data Sheet 1-49.

PHOTOGRAPHS OF ROOF DAMAGE

University Field House: Single-Ply Covering near Metal Roof

4-03-1. Overview of roof looking north. Note proximity of steeply sloped roof with wind-displaced metal panels.

4-03-2. Puncture in modified bitumen roof membrane from wind-borne debris impact.

Pool Building: Ballasted Single-Ply Covering

4-04-1. Wind damage near southeast corner.

4-04-2. Displaced metal roof panels near southeast corner.

Pool Building: Mechanically Attached Single-Ply Covering

4-05-1. Overview of wind damage on roof looking southwest.

4-05-2. Overview of wind damage on roof looking east.

4-05-3. East parapet wall with roof membrane and sheathing displaced by winds.

4-05-4. Area where wind damage began. Note stains on substrate.

4-05-5. A piece of displaced parapet sheathing. Note advanced deterioration.

Emergency Operations Center: Newer Modified Bitumen Roof

4-06-1. Delaminated and torn base flashings along windward side. Base flashings had been repositioned and temporarily re-secured.

4-06-2. Overview of wind-damaged area on roof looking northeast. Orange marks approximate southern limit of membrane billowing.

4-06-3. Roof membrane torn and lifted around drain.

4-06-4. East elevation view.

Emergency Operations Center: Older Modified Bitumen Roof

4-07-1. Overview of displaced covering on roof looking east. Note that coping metal remained in place.

4-07-2. Lightweight insulating concrete substrate with membrane displaced by winds. Note pattern of base sheet fasteners.

4-07-3. Short perimeter curb with base flashings and membrane displaced near initiation point of damage. Note open joint between pre-cast wall panels.

4-07-4. Overview of roof looking northwest.

School Campus, PE Building

4-08-1. Displaced cement wood fiber deck panels along windward edge.

4-08-2. Base sheet fasteners. Note corrosion.

4-08-3. Typical pattern of base sheet fasteners.

4-08-4. Roof edge construction.

4-08-5. Deck clip placed next to embedded reglet receiver. Note advanced corrosion of receiver.

4-08-6. Overview of wind damage on roof looking north.

School Campus, Building 1

4-11-1. Aerial view of Building 1 roof before hurricane; date unknown.

4-11-2. Roof edge construction. Note deformed cleat.

4-11-3. Overview of wind damage on roof looking south.

4-11-4 and 4-11-5. Roof edge construction. Note that fasteners securing flange of edge metal are corroded through.

School Campus, Main Building

4-13-1. Displaced roof covering looking east. Note adjacent steeply sloped roof section with metal roof covering completely removed by winds.

4-13-2. Peeled back roof membrane looking south.

4-13-3. Remnant piece of base sheet over loose-laid insulation boards secured with insulation plate and screw fasteners.

4-13-4. Roof edge construction. Note thin layer of wood installed over what are believed to be original wood nailers.

HURRICANE IVAN: TEAM 5

OVERVIEW

Team 5 deployed to the Pensacola area and concentrated on documenting the performance of metal roofing. The observations summarized in this report are based on those obtained from several extended site visits, as well as drive-by observations.

Team Members

The Metal Building Manufacturers Association (MBMA) Team 5 had the following individuals participate for at least one of the three investigation days:

W. Lee Shoemaker, Report Writer, Photographer
Floyd Patterson, Sample Collector
Jeff Walsh, Data Recorder
M. L. Rouco, Sample Collector
Dave Hunt, Data Recorder
Phil Dregger, Photographer

Scope

Figure 1 shows the general investigation area and the locations of the extended site visits.

Building Construction

Construction types surveyed included metal buildings and metal roofing on other forms of construction.

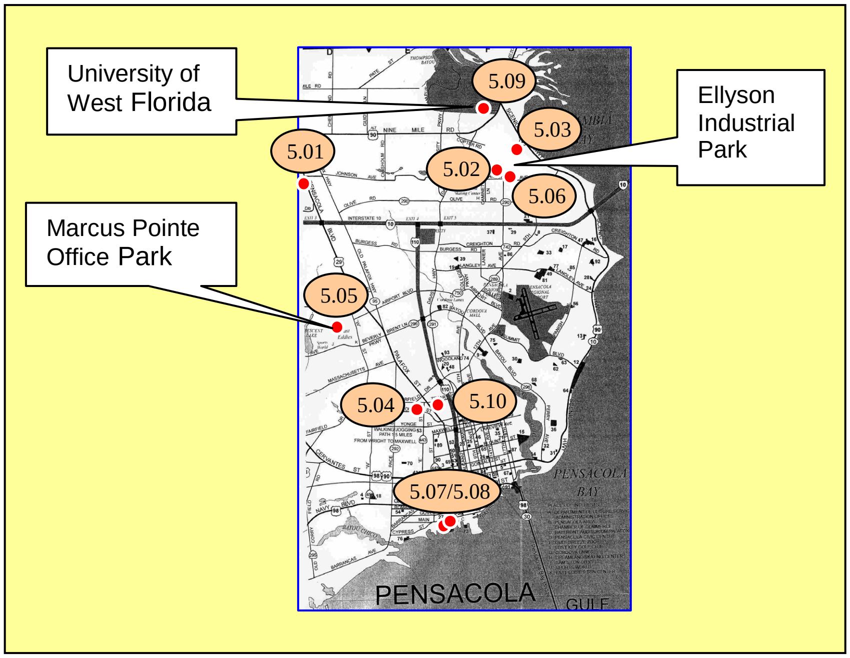


Figure 1. Area of investigation and locations of site visits.

Summary Observations

The team made the following general summary observations:

- Metal roofs that were designed and installed in the past 5 or 6 years according to the newer Florida building codes adopted after Hurricane Andrew performed very well. Exceptions were few, and roof damage was isolated to installation issues and/or internal pressurization from openings typically created by failed accessories.
- Overhead doors had a high occurrence of failure (especially in the older structures) that contributed to increased internal pressures and roof blow-off. Although newer doors performed much better, there is still a need to improve the door/building interface and to ensure that the tested door assemblies accurately reflect the in-place conditions.
- In general, in comparing metal roofs more than 10 years old, through-fastened roofs seemed to perform better than standing seam roofs. Improved test methods for standing seam roofs, along with higher roof load requirements, obviously account for the improved performance of standing seam roofs on the newer structures.
- When a standing seam roof on metal supports failed, it was almost always the clip separation from the panel seam that was the failure mode. This failure mode emphasizes the importance of the type of seam and the seaming operation.
- Most observed metal roof damage that was not associated with a door/window failure and internal pressurization, started at the eave or rake edge and progressed up toward the ridge. Poor eave or rake details, such as gutter attachments and flashing, were observed to be the weak point and the point where the failure of the roof initiated in many cases.
- When standing seam roofs were installed over wood substrates, plywood appeared to be better than oriented strand board (OSB) with regard to screw pullout. Also, fastener type and length can be a major factor in this type of roof application.
- Hip flashing appeared to suffer frequent failure or partial failure, even in otherwise well-performing metal roof installations.

INDIVIDUAL ROOF REPORTS

The following data were logged at various sites that were representative of the observed performance and/or interesting situations.

5.01 McNorton Mechanical Contractors, 1171 W. Detroit Blvd.

TYPE OF STRUCTURE—Metal building

WIND SPEED—110–120 mph

CONSTRUCTION—Typical metal building (50×175 ft.) that was expanded in the longitudinal direction (see photo 5.01-2). Original construction was in 1988; the expansion occurred in 1994. Eave height was approximately 20 ft., and the exposure was B. The through-fastened roof was on Z-purlins.

NOTED DAMAGE—The roof lifted off in the first bay adjacent to the expansion. All roof panels in this bay were gone (some in the side yard), and several Z-purlins were torn off and in the side yard. The purlin lap used in the expansion was questionable, with two no. 12 screws used in the webs. A total of six rollup doors (12×12 ft.) on the left side of the building were all damaged and breeched.

DAMAGE INITIATION AND PROPAGATION—Blown-in rollup doors were probably the initiating failure; the increased internal pressure blew out the roof in the bay, the purlin laps being the weak point that led to the bay failure.

5.02 Dana Fluid System Products, 9101 Ely Rd. (Ellyson Industrial Park)

TYPE OF STRUCTURE—Metal building

ROOF SLOPE—2”:12”

WIND SPEED—110–120 mph

CONSTRUCTION—Typical metal building (250×470 ft.) with 22-ft. eave height was built in 1985. Roof construction used a standing seam roof with 20-in. flat pan “T” panels with 2⅝-in. ribs supported on bar joists on 5-ft. centers. A roof coating had been applied within the past few years.

NOTED DAMAGE—The standing seam roof disengaged from clips along the windward rake. The damaged area extended 75 ft. downslope from the ridge and 20 ft. in from the rake.

DAMAGE INITIATION AND PROPAGATION—The standing seam roof released from the clips and dislodged the batten caps. All of the clips remained screwed to the bar joists. No doors were breeched, and there appears to have been an edge-zone failure where pressures exceeded the uplift capacity of the standing seam roof system.

5.03 Climatic Comfort Products, 3371 Addison Drive

TYPE OF STRUCTURE—Metal building

ROOF SLOPE—½”:12”

WIND SPEED—110–120 mph

CONSTRUCTION—Metal building with precast concrete walls was built in 1994 and is 60×125 ft. with an 18-ft. eave height. The roof construction is trapezoidal standing seam, 24-in. panels, 24 gage, on cold-formed Z-purlins at 5-ft. centers. Eave attachment is by four screws through panel flats into eave trim and clip at eave purlin.

NOTED DAMAGE—Two areas of the roof suffered blow-off: half of the end bay and a fourth of the interior bay. Also, a 12×12 ft. overhead door was breeched.

DAMAGE INITIATION AND PROPAGATION—At both locations, roof panels peeled back. All eave trim was damaged on the windward side. Eave fasteners pulled out of the trim, possibly after the building was pressurized from door failure.

5.04 Escambia School Maintenance Building, Texar Drive at Miller

TYPE OF STRUCTURE—School maintenance building

ROOF SLOPE—3”:12”

WIND SPEED—110–120 mph

CONSTRUCTION—Vehicle maintenance building was built in 1984. Roof construction is 18-in. flat pan vertical seam “T” panel with 2⅝-in. ribs. The building is 100 ft. wide with a 20-ft. eave height. The roof is supported by bar joists on 5-ft. spacing. Standing seam roof clips were attached with one screw per clip.

NOTED DAMAGE—The roofing over the windward end bay blew off. Damage extended 12 ft. from the rake, over the entire width of the building. An overhead door (14×12.5 ft.) at the end bay blew in. Also, a large soffit area was blown out on the east side, contributing to building pressurization.

DAMAGE INITIATION AND PROPAGATION—Internal pressurization probably led to end bay roof blow-off.

5.05 Folkers Window Company, 5030 Commerce Park Circle (Marcus Pointe)

TYPE OF STRUCTURE—Metal building

ROOF SLOPE—¼”:12”

WIND SPEED—110–120 mph

CONSTRUCTION—Metal building was constructed in 1997 with precast concrete walls. Building is 150 ft. wide × 220 ft. long with a 20–24 ft. eave height. The roof is standing seam on Z-purlins. Standing seam roof is trapezoidal, 24 gage, rolled seam. Two no. 12 screws per clip were used. The eave was attached with five screws per flat into the eave trim, which was 26 gage. (Exposure B.)

NOTED DAMAGE—The standing seam roof was blown off on windward, the end wall from the eave to about three-fourths of the way up the ridge.

DAMAGE INITIATION AND PROPAGATION—The eave detail had a standing seam roof screwed into the eave trim. Apparently wind-borne debris caused damage to the eave gutter, essentially pulling the eave trim down and separating the standing seam roof. The damage initiated here and peeled back toward the ridge.

5.06 Empire Truck Sales, 8801 Paul Star (Ellyson Industrial Park)

TYPE OF STRUCTURE—Metal building

ROOF SLOPE—1”:12”

WIND SPEED—110–120 mph

CONSTRUCTION—Metal building was constructed in 1988 with masonry walls. Building is 50 ft. wide with 10-ft. structural eave canopies on both sides. The length of the building is 240 ft. (four 60-ft. bays) with an eave height of 18 ft. The building has a wash bay at the south end with a concrete masonry unit (CMU) wall separating it from the other bays. Six large roll-up doors (three on each side), 14×16 ft., are present. Roof is through-fastened “R” panel, on continuous Z-purlins at 5-ft. centers, fastened at 12 in. on-center (o.c.).

NOTED DAMAGE—All panels were lost on the east canopy. Roof blow-off occurred at the end opposite the CMU wall for one-half of the bay. All of the east-facing roll-up doors were lost, and all but one of the west-facing walls was lost. In some cases, the door track separated from the masonry walls where the anchors pulled out. The CMU wall blew out, but it had already been repaired when the site was visited by the team. (Open exposure C, wind from southeast.)

DAMAGE INITIATION AND PROPAGATION—Failure of the roll-up doors caused pressurization and caused the CMU wall to blow out. Part of the cause for the roof blow-off was probably a combination of the internal pressure and the failure of overhang canopy sheeting that propagated up toward the ridge.

5.07 Hope Lumber, Office and Sales, 1500 W. Main St.

TYPE OF STRUCTURE—Metal building

ROOF SLOPE—1”:12”

WIND SPEED—110–120 mph

CONSTRUCTION—Metal building with metal wall panels was constructed in 1984. The building has a sales floor and offices in the north end and a warehouse in the south end. The building is 100 ft. wide by 150 ft. long with an eave height of 24 ft. The roof construction is aluminum through-fastened

R panels on Z-purlins at 5 ft. o.c. The building appears to have been re-roofed, based on the condition of the roofing versus the siding.

NOTED DAMAGE—Roof panels were blown off in two areas. About two bays (50 ft.) of panels at the windward end of the building (warehouse area) and a 30×40 ft. area of roof panels were blown off beginning at the corner at the leeward end of the building. The building had two 10×10 ft. roll-up doors that had been blown in on the windward end wall. (Exposure C.)

DAMAGE INITIATION AND PROPAGATION—The internal pressurization from two lost overhead doors was probably the initiation of the roof blow-off.

5.08 Hope Lumber, Lumber Storage Shed, 1500 W. Main St.

TYPE OF STRUCTURE—Commercial

ROOF SLOPE—1”:12”

WIND SPEED—110–120 mph

CONSTRUCTION—Open-sided lumber storage shed was built around 1997. The building is 35 ft. wide and 150 ft. long. The single-slope roof has a low side eave height of 16 ft. Metal wall panels are on the two end walls and the low side wall. The high side wall is open. The roof construction was through-fastened R panels on Z-purlins that varied from 3 to 4 ft. o.c.

NOTED DAMAGE—90% of the roof suffered blow-off, and 80% of the end walls lost wall panels. Some damage occurred to the cold-formed secondary members (Z-purlins) at the high side eave. Some girt damage on end walls.

DAMAGE INITIATION AND PROPAGATION—Inconclusive, but wind direction was the worst-case scenario with regard to damage, and it accounted for this shed’s being heavily damaged compared with a similar shed located where the wind direction was not perpendicular to the open side.

5.09 Building No. 54 (Field House), University of West Florida

TYPE OF STRUCTURE—University

WIND SPEED—110–120 mph

CONSTRUCTION—Field house was built around 1970. Of interest to the team was the mansard roof/siding around the perimeter of the building. The building height was approximately 45 ft. The mansard was made of an aluminum outer skin, 16-in. panels, 0.04-in. thickness, that was attached to a steel deck (12-in.-wide panels) with aluminum straps and concealed aluminum cleats. Fiberglass batting insulation was sandwiched between the layers. The connection of the aluminum panels was at 22 in. from the top and then at spans of approximately 6 ft. 10 in., depending on the locations of the straps and cleats. The slope of the mansard face was 68°.

NOTED DAMAGE—The aluminum outer panels were torn from the steel deck substrate over a wide area of the mansard.

DAMAGE INITIATION AND PROPAGATION—The attachment of the aluminum cleat to the steel deck substrate (one screw per cleat) was the most commonly observed failure. The capacity of this connection was not adequate for the wind pressures that impacted the roof/building.

5.10 City of Pensacola Public Works Dept, 2757 N. Palafox

TYPE OF STRUCTURE—Metal building

ROOF SLOPE—1”:12”

WIND SPEED—110–120 mph

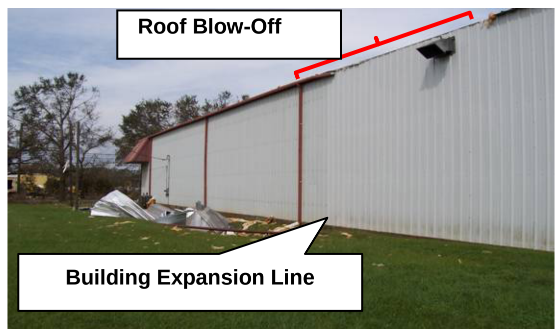
CONSTRUCTION—Two-story metal building, approximately 75×100 ft. with an 18-ft. eave height. Roof construction is 24-in. trapezoidal standing seam on Z-purlins at 5-ft. centers.

NOTED DAMAGE—A row of standing seam panels (second row in from rake) was blown off.

DAMAGE INITIATION AND PROPAGATION—This was an interesting failure with regard to the location of the roof blow-off. It was the only case seen in which the failure did not initiate at the edge of the roof. Workmanship in seaming may have been an issue.

PHOTOGRAPHS OF ROOF DAMAGE

5-01-1. McNorton building. Left side showing overhead door damage.

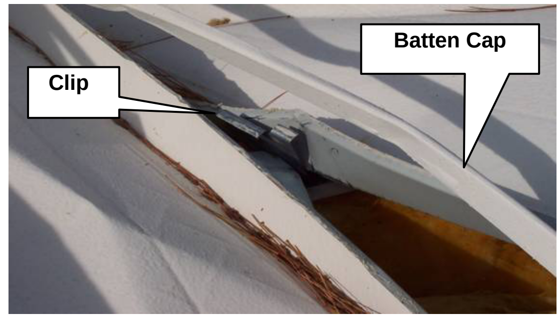


5-01-2. McNorton building. Right side of building showing expansion and roof failure area.

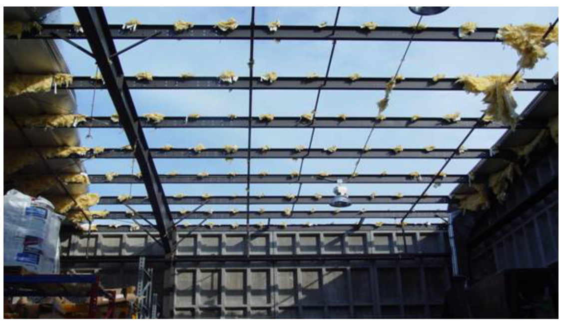
5-01-3. McNorton building. Lapped purlins at building extension.

5-02-1. Dana building. Interior view of roof damage at windward end.

5-02-2. Dana building. Standing seam roof damage showing dislodged batten caps.

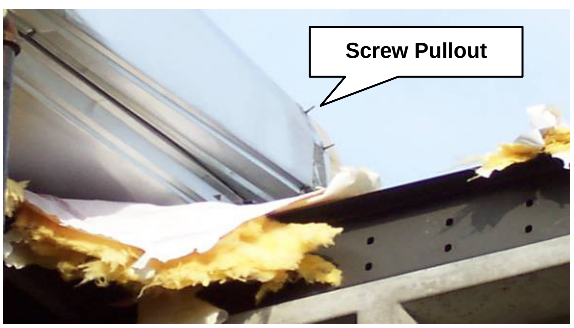


5-02-3. Dana building. Open seam showing dislodged batten cap and clip.



5-03-1. Climatic Comfort Products building. End bay showing all clips still attached to Z-purlins.

5-03-2. Climatic Comfort Products building. Interior bay showing roof panels peeled away.



5-03-3. Climatic Comfort Products building. Attachment of panel to eave trim—screw pullout.

5-04-1. Escambia School Maintenance building. Sidewall—overhead door and soffit failure.

5-04-2. Escambia School maintenance building. End bay roof failure area, temporary repair in place.

5-04-3. Escambia School maintenance building. Clips in batten cap.

5-05-1. Folkers Window Company. End of building where roof damage occurred.

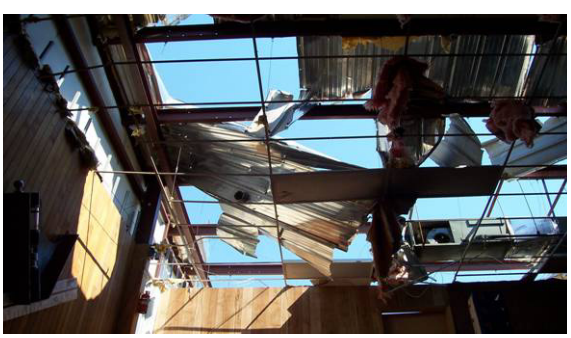
5-05-2. Folkers Window Company. View from below showing screws penetrating eave trim.

5-05-3. Folkers Window Company. Gutter damaged by falling tree.

5-06-1. Empire Truck Sales. Failed roll-up doors on east side of building.

5-06-2. Empire Truck Sales. Structural canopy on east side of building that lost sheeting.

5-06-3. Empire Truck Sales. CMU wall on south end that was blown out and repaired.



5-07-1. Hope Lumber office. Roof blown off at north end of building (windward).

5-07-2. Hope Lumber office. Underside of aluminum R-panels.

5-07-3. Hope Lumber office. One of the large roll-up doors that was breeched.

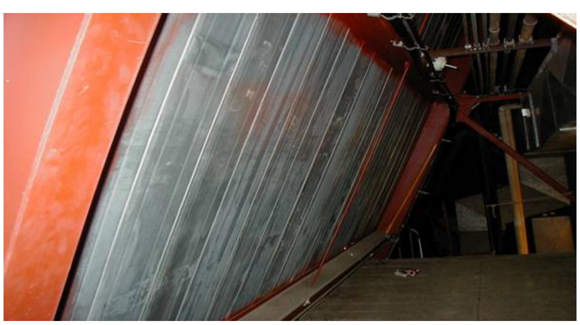
5-08-1. Hope Lumber storage shed. Open-sided shed that lost its roof.

5-08-2. Hope Lumber storage shed. Remaining roof panels on lumber shed.

5-08-3. Hope Lumber storage shed. Shed on other side of yard with only minor trim damage.

5-09-1. Bldg 54–University of West Florida. Failed mansard covering—strap attachments shown.

5-09-2. Bldg 54–University of West Florida. Failed connection of aluminum panel to steel liner.



5-09-3. Bldg 54–University of West Florida. Inner side of steel deck on structural framework.

5-10-1. Pensacola Public Works. End of building where roof failure occurred.

5-10-2. Pensacola Public Works. Inside showing panels blown off and repaired with plywood.

5-10-3. Pensacola Public Works. Uneven alignment of panels at eave.

HURRICANE IVAN

STEEP SLOPE ROOF SYSTEMS

HURRICANE IVAN: TEAM 3

OVERVIEW

Team 3 members investigated a variety of steep-pitched roofs. The team attempted to find roofs with a variety of wind exposures and systems. Storm reports at the time of the RICOWI investigation indicated that Ivan's hurricane force winds were slightly below those specified by the building code for the area. Buildings located on the barrier islands were expected to be exposed to higher unobstructed wind speeds. The team was interested in observing roofs located in and around the path of the hurricane's eye.

Team Members

The following individuals participated on Team 3 for at least one of the four investigation days:

Joe Wilson, Report Writer
Dave Hunt, Sample Collector
Mike Vaille, Photographer
Maria Luisa Rouco, Data Recorder
Eric Haefli, Photographer
Brad Davis, Observer
J. Myslak, Observer

Scope

Team 3 visited residential and commercial areas impacted by Hurricane Ivan that were in or relatively close to Pensacola, Florida. Specifically, the team investigated structures at the University of West Florida, Bayshore Drive, downtown Pensacola, Pace, West Pensacola, Gulf Beach, and Perdido Key.

Building Construction

The team surveyed a total of 17 roofs: through-fastened metal roofs, 8 composition shingle roofs, 2 metal shingle roofs, and 1 wood shake roof. In addition, team 3 did quick surveys on four streets to gain a larger perspective on the hurricane's overall impact. The quick street survey (Table 1) classified roof damage in four categories: none, minor, partial, and major damage. (All of these roofs were in the 110–120 mph wind speed area.)

Summary Observations

- Many of the areas examined were surrounded by tall pine trees and live oak trees. It is hypothesized the densely spaced trees helped shelter structures from the winds, therefore reducing damage. However, roofs were damaged by falling trees. Most of the severe damage from falling trees was the result of tall pines snapping at about 10–20 ft. above the ground.
- The storm surge was the largest contributor to debris in the areas around the bays and shorelines. We did not see any evidence of inland flooding.
- Although many roofs were damaged to some degree by the hurricane, in many instances roofing systems remained intact. However, for most building inspections, it was not possible to determine if there was interior water damage due to wind-driven rain through the roofing system.

Table 1. Amount of roof damage observed in quick street survey (number of houses)

Location and type of roof	Wind speed	None	Minor	Partial	Major	Total
Mackey Cove	110–120					
Composition shingle			2	2	13	17
Stone-coated steel shingle		2	1			3
Standing seam metal		1			3	4
Port Royal	110–120					
Cement tile		1	9			10
Composition shingle			1			1
Tiger Point Blvd.	100–110					
Composition shingle			18	15	18	51
Cobblestone Dr.	100–110					
Composition shingle		7	2	13	5	28
Stone-coated steel shingle		1				1

Observed Damage Modes

Insufficient Attachment. Insufficient fastener attachment was commonly observed in both the types and the number of fasteners used. Cases were observed where the fastener type (related to withdrawal resistance) was not sufficient, in conjunction with the frequency of placement, to resist the wind forces. Examples of roof damage occurred where fasteners and placement patterns were used that would not normally have been specified or prescribed for a particular application. It was found that the fastening requirements specified in a later version of the building code were an improvement over those of the earlier code. Insufficient attachment was also prevalent in the securing of substrates and framing members.

Workmanship. The team observed instances where the construction of the roof compromised its performance against the hurricane-force winds. Cases were found of missing or improperly placed fasteners. Other cases were found where the construction of the building’s roof covering was not according to the governing code or standard practice at the time of construction.

Improper Material Selection. Examples were found of roofs where either one component or a combination of components failed to withstand the force of winds. The failure of one component on the roof or used as part of the roof structure was found to influence the performance of other materials. Roofs that were exposed to and survived the hurricane winds were supported by an entire system having the required materials installed according to specification.

Structural Failure. Cases were observed in which the structural integrity of the building was breached and the roof failed. Structural failure caused by wind pressure or internal pressurization was uncommon, however.

Age and Maintenance. In some cases in which similar material types were used, newer roofs performed better in the hurricanes than did older materials. Some of the performance differences between older and newer materials can be attributed to better-specified application methods, but in similar roofs with equivalent application methods, it was observed that newer roofs fared better than older ones. Examples were found in which the performance of the roof was weakened by corrosion or deterioration of components.

Winds in Excess of Design. In some instances, the roof system failed even though it was constructed according to an appropriate updated specification. These examples were found for both the roof system and the building’s structure.

Individual Building Reports

3.01 Police Station, University of West Florida, Pensacola

TYPE OF STRUCTURE—Commercial

EXPOSURE—B

ROOF SYSTEM—Copper raised seam

ROOF SLOPE—6":12"

ROOF DECK—Plywood and 2×2 battens

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—8D nails, 24 in. o.c.

NOTED DAMAGE—40% of roof damaged

DESCRIPTION—2×2 wood battens fastened with 8D nails spaced 16 in. o.c. Battens were not spaced over the rafters, and battens pulled away from the decking. An insufficient number of nails and location of nails for battens resulted in failure to hold the roof in place. Leading edges of copper panels were unanchored. Panels came off as a result of batten pull-off.

3.02 Pensacola Pro Shop, Country Club Dr., Pensacola

TYPE OF STRUCTURE—Commercial

EXPOSURE—C

ROOF SYSTEM—Composition shingles

ROOF SLOPE—6":12">

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—1¼-in. roofing nails, 10 in. o.c.

NOTED DAMAGE—25% of roof damaged, beginning from corner/eave.

DESCRIPTION—Shingles not sealed at eaves. Only four nails per shingle. Shingles tore loose from the rake edge at the lower corner and unzipped further into field.

3.03 1114 Harbor View Circle, Pensacola

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

ROOF SYSTEM—Composition asphalt shingles

ROOF SLOPE—6":12"

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—Roofing nails, six per shingle

NOTED DAMAGE—Small amount of damage at hips

DESCRIPTION—Minimal damage occurred only at hips. Most of the roof is undamaged. Approximately one-year-old roof.

3.04 1015 Harbor View Circle, Pensacola

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

ROOF SYSTEM—3-tab asphalt shingles

ROOF SLOPE—6":12"

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—Roofing nails, four per shingle

NOTED DAMAGE—30% of roof damaged

DESCRIPTION—Shingles were not sealed adequately at the tab, and they lifted and ripped loose; four nails per shingle. This was a 3-tab roof, 10 years old.

3.05 833 Bayshore Dr., Pensacola

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

ROOF SYSTEM—Through-fastened metal

ROOF SLOPE—4–6" 12"

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—1-in. screws, 24 in. o.c.

NOTED DAMAGE—One panel lifted up

DESCRIPTION—Lap seam was lifted up, but it was attached with one screw over a 20-ft. span. Panels did not loosen from roof.

3.06 833D Bayshore Dr., Pensacola

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

ROOF SYSTEM—Granular coated steel shingles

ROOF SLOPE—6":12” or greater

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—2-in. screws, 12 in. o.c.

NOTED DAMAGE—No damage

DESCRIPTION—Mansard style roof

3.07 Brownsville Baptist Church, 261 Strong St., Brownsville

TYPE OF STRUCTURE—Multi-story church

EXPOSURE—B

ROOF SYSTEM—Architectural metal

ROOF SLOPE—6":12" >

ROOF DECK—Composite fiber and 1×4 battens

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—1½-in. screws spaced 12 in. o.c. into 1×4 battens

NOTED DAMAGE—Entire roof and portions of roof deck blew off

DESCRIPTION—1×4 battens screwed to composite fiber decking with 4-in. no. 12 fasteners spaced randomly (2–4 ft). The screws pulled from the decking universally. The metal roof launched entirely free from the decking. No damage occurred.

3.08 Gregory Center, 418 Gregory, Pensacola

TYPE OF STRUCTURE—Commercial

EXPOSURE—B

ROOF SYSTEM—Sprayed polyurethane foam (SPF)

ROOF SLOPE—Flat

ROOF DECK—2-in. thick polyisocyanurate board, plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—2-in. ring shank nails, six per 48-in. panel

NOTED DAMAGE—30% of roof damaged

DESCRIPTION—Nailer on top of parapet wall was nailed with 16D nails into brick (decorative). The 2×10 nailer was attached to the bricks with cement (in some cases) holding bolts anchoring the nailer. The nailer came loose easily at the edge. The edge nailer was not connected to the main structure. The SPF roof came loose as a result of the unattached nailer. Large rooftop mechanical units were blown off the roof, exposing two large holes in the roof deck. This may have contributed to part of the roof membrane damage.

3.09 McGuire’s Restaurant, 600 Gregory, Pensacola

TYPE OF STRUCTURE—Single story restaurant

EXPOSURE—C

ROOF SYSTEM—Wood shakes

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—2-in. nails, two per piece

NOTED DAMAGE—15% of roof damaged

DESCRIPTION—The restaurant is an older building with a faux-mansard roof/parapet on top of a low slope roof. The faux-mansard is made of plywood on wood framing with a wood shake on building paper roof membrane; the wood framing support is open in the back. The faux-mansard is secondary and not part of the roof system that keeps weather from entering the building. Wood shakes were nailed at 20 in. from the butt edge, allowing excessive movement. Wood shakes were laid on a staggered pattern, so nail spacing was most likely determined on the basis of ease of installation, not on the basis of building code. Two nails were used per shake. Some ridge loss occurred because of nailing too far back on the pieces, resulting in nail pull-through.

3.10 3804 Tiger Point East, Pensacola

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

ROOF SYSTEM—Composition asphalt shingle

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—1¼-in. roofing nails, six per shingle

NOTED DAMAGE—20% of roof damaged

DESCRIPTION—Roof is approximately 10 years old or more. Tabs lifted up and tore shingles from nails.

3.11 3806 Tiger Point East, Pensacola

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

ROOF SYSTEM—Composition asphalt shingle

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—1¼-in. roofing nails, six per shingle

NOTED DAMAGE—5% of roof damaged

DESCRIPTION—Very minor damage with approximately six hip pieces lost. Roof is one month old.

3.12 3317 Village Green, Pace

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

ROOF SYSTEM—Composition asphalt shingle

ROOF SLOPE—4–6":12"

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—1¼-in. roofing nails, four per shingle

NOTED DAMAGE—Very minor damage

DESCRIPTION—Minor damage with loss of approximately six hip pieces; 1-month-old roof.

3.13 3321 Village Green, Pace

TYPE OF STRUCTURE—Single family home

EXPOSURE—C

ROOF SYSTEM—Composition asphalt shingles

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—100–110 mph

METHOD OF ATTACHMENT—1¼-in. roofing nails, four per shingle

NOTED DAMAGE—50% of roof damaged

DESCRIPTION—Gable style roof had major shingle loss. The hip house next door had very little damage, but this house had major damage with the same nailing. Gable versus hip construction and 1- versus 2-story height was the difference between the roofs. Houses on this street with hip roofs did well; houses with gable roofs did not.

3.14 5029 Highpoint Dr., West Pensacola

TYPE OF STRUCTURE—Single family home

EXPOSURE—B

ROOF SYSTEM—Composition asphalt shingles

ROOF SLOPE—6":12"

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—1½-in. roofing nails, six per shingle

NOTED DAMAGE—50% damaged in field

DESCRIPTION—Five-year-old shingles attached with six nails per shingle. Tabs lifted up and shingles tore from fasteners on three of the four faces of the home.

3.15 High Pointe Club House, West Pensacola

TYPE OF STRUCTURE—Golf clubhouse

EXPOSURE—C

ROOF SYSTEM—Standing seam metal

ROOF SLOPE—4 to 6":12” >

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—Clips

NOTED DAMAGE—None

DESCRIPTION—1½-in. raised, 20 in. wide. The standing seam roof on the clubhouse was clearly exposed. No damage.

3.16 Greek Orthodox Church, K and Garden, Pensacola

TYPE OF STRUCTURE—Multi-story church building

EXPOSURE—B

ROOF SYSTEM—Raised seam copper

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—Clips

NOTED DAMAGE—None

DESCRIPTION—18-in.-wide copper standing seam roof on the church showed no damage. The roof was 0.021-in.-thick copper.

3.17 10535 Gulf Beach Hwy., Gulf Beach

TYPE OF STRUCTURE—Multi-story single family home

EXPOSURE—C

ROOF SYSTEM—Metal shingles

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—Clips with 1¼-in. nails in each clip spaced 10 in. o.c.

NOTED DAMAGE—75% of roof damaged

DESCRIPTION—Steel shingle roofing (panel size 10×40 in.) came loose around the top sections of the house, beginning from an eave where some of the edge metal deformed from the panel-locking position. Panel clips, still attached to the decking, deformed and released the panels. Sections of panels came loose from clips, resulting in the release of the next course of panels.

3.18 14000 Perdido Key Dr., Perdido Key

TYPE OF STRUCTURE—Multi-story commercial building

EXPOSURE—C

ROOF SYSTEM—Standing seam metal

ROOF SLOPE—6":12" >

ROOF DECK—Plywood

WIND SPEED—110–120 mph

METHOD OF ATTACHMENT—Clips with 2×1¼-in. screws spaced 24 in. apart

NOTED DAMAGE—80% of roof damaged

DESCRIPTION—Building had unenclosed 4-ft. scab-nailed truss overhangs. Plywood was nailed 6 in. o.c.; the plywood released from the scab trusses, and the overhangs were pulled off the building. The resulting overhang deck and truss failure initiated the metal panels being pulled entirely free from the roof. Clip spacing was 24 in. o.c., and seams were screwed together (seams unfolded) with screws spaced 6 ft. o.c. The metal roofs were blown almost entirely off the building, along with sections of overhangs.

PHOTOGRAPHS OF ROOF DAMAGE

Police Station, University of West Florida

3-01-1. Raised seam copper panels attached to battens came off because battens came loose.

Pensacola Pro Shop

3-02-1. Damage to composition shingle roof began at corner and rake edge.

1114 Harbor View Circle

3-03-1. Damage to composition shingles was limited to hip section.

1015 Harbor View Circle

3-04-1. Tabs that were not sealed down tore loose from 10-year-old shingle roof.

833 Bayshore

3-05-1. Through-fastened metal roof with lifted panel missing fasteners at seam.

833D Bayshore

3-06-1. Undamaged steel shingles and metal panels.

Brownsville Baptist Church

3-07-1. Metal panels attached to 1×4 battens pulled loose from composite fiber decking.

McGuire's Restaurant

3-09-1. Missing wood shakes that had been laid in staggered pattern to enhance aesthetics.

3804 Tiger Point East

3-10-1. Shingle tabs lifted and tore loose on 10-year-old roof.

3806 Tiger Point East

3-11-1. Shingle roof missing only six hip pieces.

3317 Village Green

3-12-1. Home next door to house shown in 3-13-1 lost only a few hip pieces.

3321 Village Green

3-13-1. Wind damage to shingles at rake edge.

5029 Highpoint Drive

3-14-1. Damage to 5-year-old shingle roof where tabs lifted and tore loose.

High Pointe Club House

3-15-1. Undamaged standing seam roof on clubhouse.

10535 Gulf Beach Highway

3-17-1. Steel shingles blown loose from attachment clips.

14000 Perdido Key Drive

3-18-1. Beach-front building suffered damage to structure and standing seam roof.

CONCLUSION

RESULTS

The investigation of Hurricanes Ivan and Charley provided valuable information on the performance of roofing exposed to hurricane-force winds. The investigation teams were able to discern the effectiveness of materials and methods of construction in resisting these winds. A variety of damage modes were observed in the hurricane-struck areas, including roof attachment, material selection, roof/structure design, deterioration, and workmanship. Many of the performance characteristics observed in Hurricane Charley were again observed in Ivan. During the investigations of Ivan and Charley, our teams found that generally roofing installed according to the latest codes resisted damage from the winds. The information gathered on some types of materials provides an understanding of the materials' performance characteristics when installed in accordance with the customary method for that area. The participating associations will develop specific recommendations for new installation procedures and building code changes based on the data and reports.

The investigations were also a learning laboratory for the investigation procedures used. It was clearly shown that investigations need to be under way soon after landfall to capture the progression of damage. Repairs of essential facilities are usually under way as soon as debris can be adequately cleared and access is available. A preliminary assessment team with flyover and aerial photo capabilities provides the information that allows the best use of resources in the investigations. This is most important in locating low slope rooftops that cannot be observed from the ground. Logistics is critical to successful investigations. Housing near the inspection area, although difficult to obtain, led to effective use of the manpower resources provided in these investigations.

Installation of roofs systems as a minimum should meet the minimum code requirements in hurricane zones and follow best industry practices and manufacturers' guidelines. Owners and specifiers are urged to consider designing systems that exceed current code requirements. Systems should follow the performance requirements, including appropriate testing, specified by the applicable building code.

All building envelope components are affected by weather-related aging; therefore, sufficient maintenance of buildings is important. The studies reinforced the need for secure roof edges, and codes that require secure roof edging need to be enforced. Wind-borne debris was also a major contributor to roof damage, and standards and enforcement are needed for attachment of all building envelope components to help reduce wind-borne debris (e.g., air handling units).

FUTURE RESEARCH

Future hurricane wind investigations would prove valuable in collecting additional information on the performance of roofing exposed to hurricane force-winds. Some questions or suppositions were resolved from information gathered during the Charley and Ivan events; but, at the same time, other questions surfaced. For example, it was observed that some roofing materials were more prone to damage when located on gable-constructed homes or around wall protrusions or dormers. More investigations are necessary to verify these and other observed phenomena. Although an effort was made to investigate all types of roofing, some types were not found in the areas affected by Charley and Ivan. Therefore, further investigation is warranted in areas that contain other types of roofing or construction methods not previously observed.

In particular, it would be valuable to conduct an additional survey in the same areas previously investigated by our teams, or in a location that had recently been rebuilt after a hurricane. Also of interest would be investigations in areas that have installed substantial amounts of roofing in accordance with the latest code revisions. Questions regarding the adequacy of the building code arise after an area is ravaged by a hurricane, and investigations are warranted when serious questions are raised by governing authorities. Investigations can distinguish whether the damage is caused by non-conformance to code standards or if the code is adequate. The goal of RICOWI investigations is to gather the facts, and facts are necessary when there is a general push for change that is perhaps fueled by supposition or concerns raised by false information. The unique, balanced composition of RICOWI teams (members from industry, science/research, and consultation) results in the documentation of facts without bias.

RICOWI investigations are conducted with a forensic scope and are not intended for statistical analysis, but the investigation criteria in future events might be amended to allow for larger samplings. Other search criteria could be added, as appropriate, to gather information not previously considered. The criteria for event mobilization could be modified according to the information that might be desired from a particular area impacted by a hurricane. In other words, in the future, the decision regarding whether to activate for an investigation can be based more on the potential value of the information to be gathered, rather than the prior criteria based on a hurricane with 95-mph (one minute sustained) winds striking any major populated area in the continental United States.

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Bill Young, Jr./Florida Solar Energy Center

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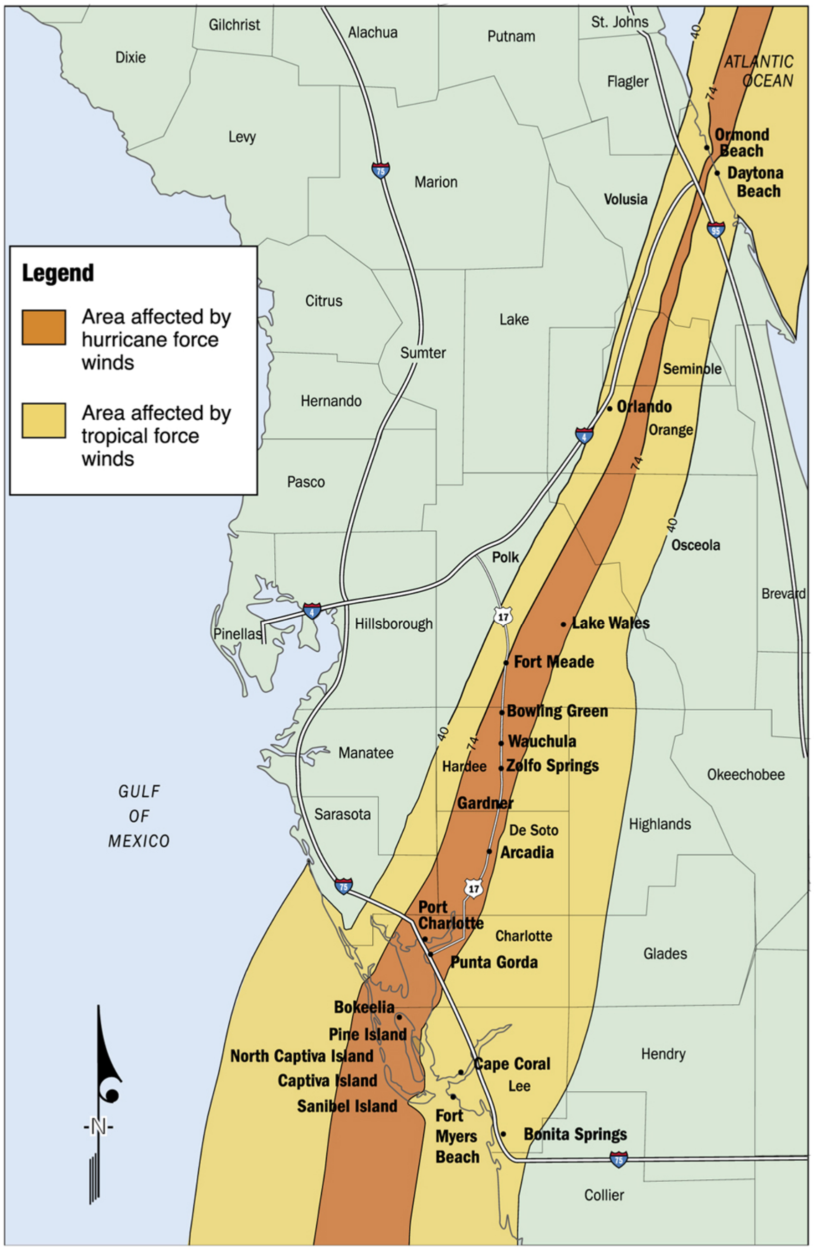
- Shabbar Saifee and Paul Tertell (FEMA) for their support and coordination with our logistics teams, and Curtis Andrews, Sal Bucolo, Stan Houston, Chris Nery and Lonnie Ryder, all FEMA volunteers that joined Hurricane Charley teams.
- The photographers and report writers on each team for the long hours required to sort and caption photographs and write team reports. Phil Mayfield took on the arduous task of editing the first draft of the majority of the reports.
- Peer reviewers Dr. James McDonald and Dr. Robert Wardlaw.
- Finally, we are grateful to the people in the hurricane-ravaged areas for their cooperation and hospitality. These people lost so much and yet had the most positive attitude, continually exhibiting a willingness to help.

We anticipate that the lessons learned from these investigations will help to improve products and construction methods that will limit the extent of damage from future hurricanes.

Appendix A. Hurricane Charley—Estimated Extent of Hurricane and Tropical Force Winds Map

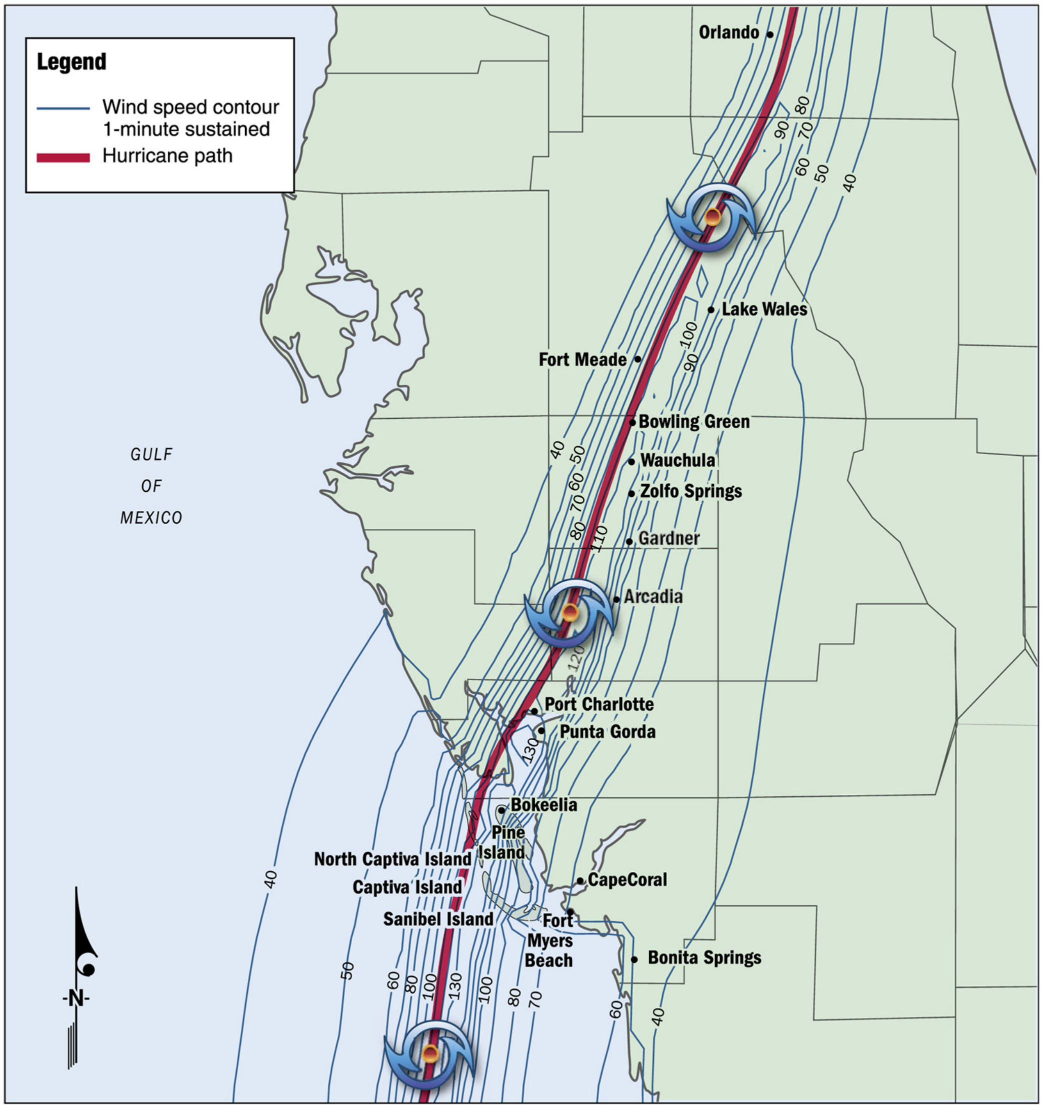


Extent of the hurricane and tropical storm force winds for Hurricane Charley as estimated by the NOAA H-wind model.

Map used courtesy of NOAA Experimental Research Products.

Appendix B. Hurricane Charley

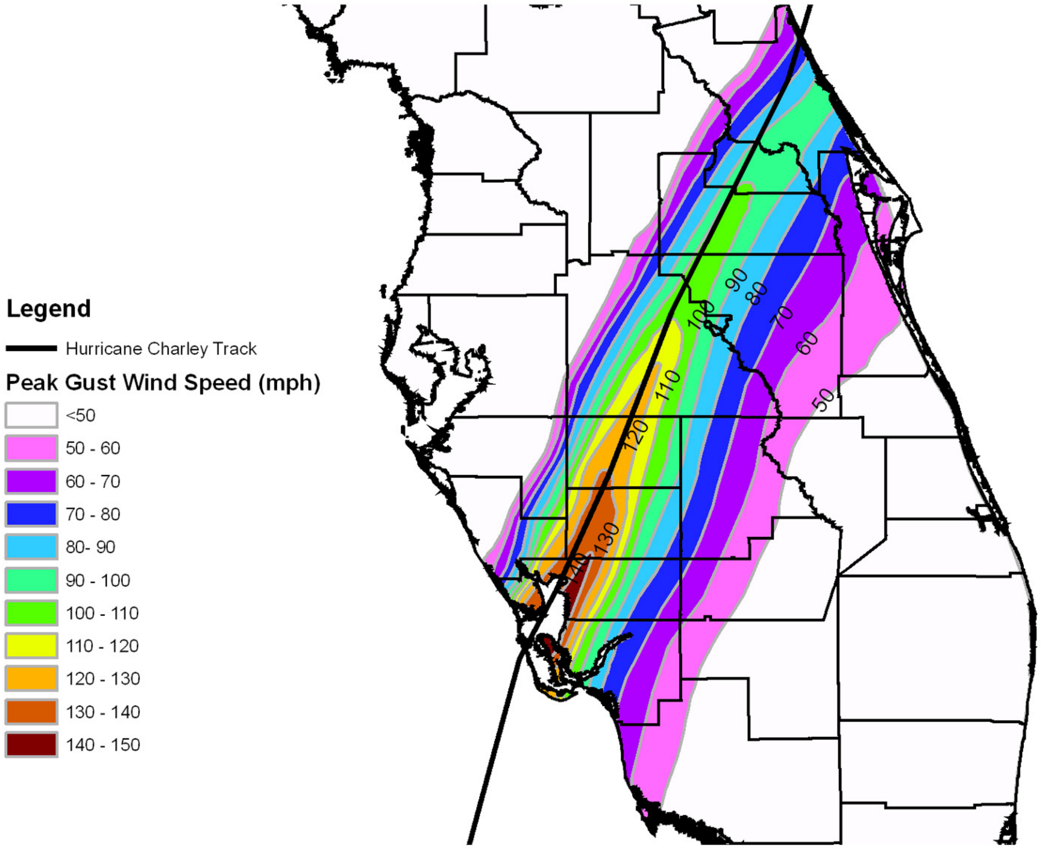
Wind Swath Analysis Map



Results of the preliminary H-wind swath analysis for Hurricane Charley.

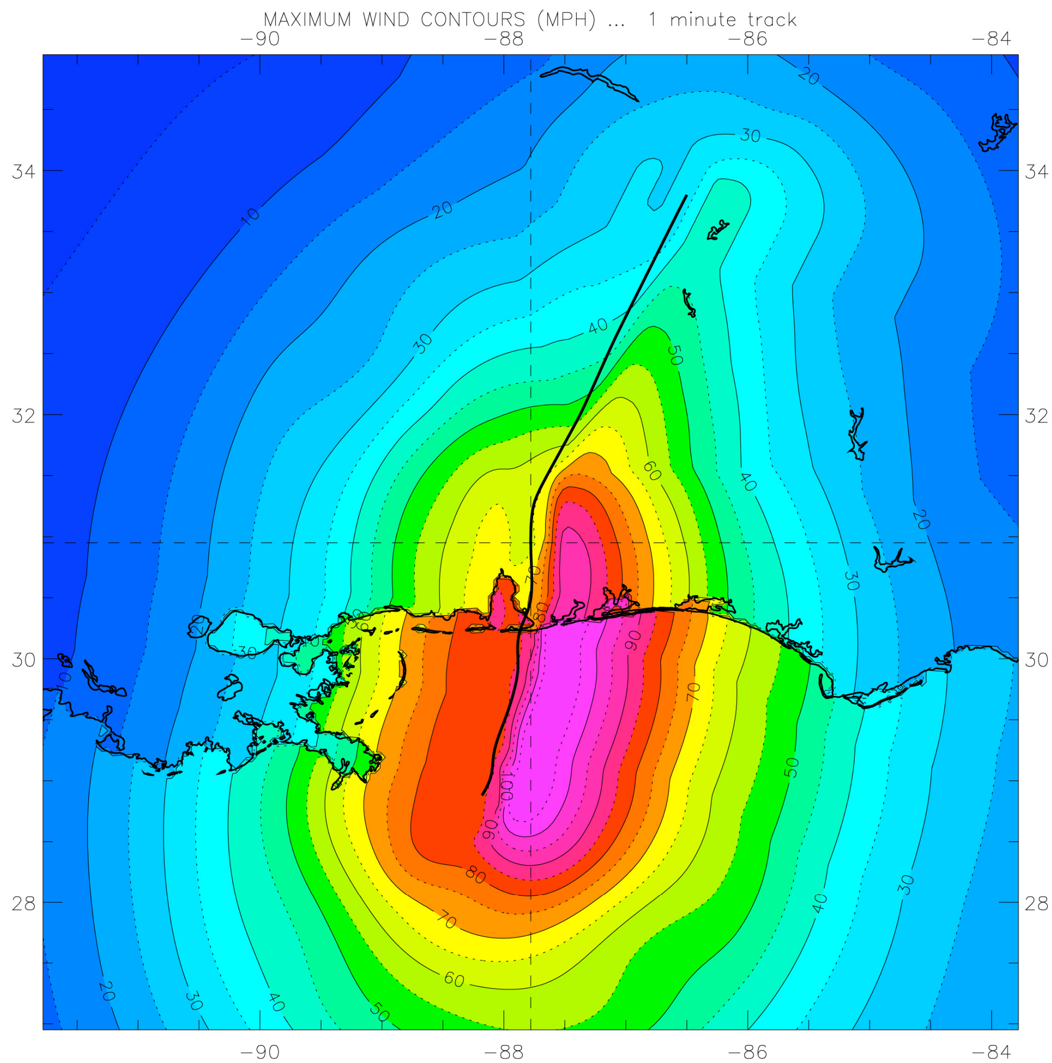
Map used courtesy of NOAA Experimental Research Products.

Appendix C. Hurricane Charley Wind Speed Map



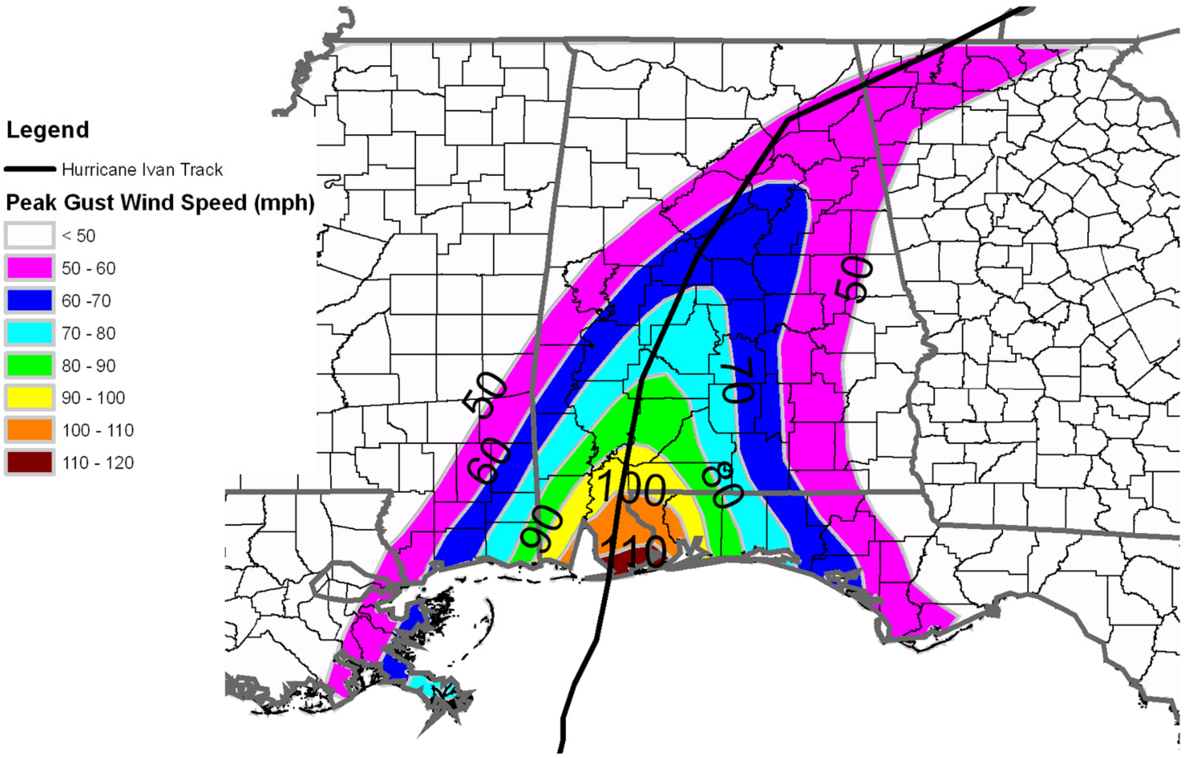
Map used courtesy of Applied Research Associates.

Appendix D. Ivan Maximum Wind Contours Map



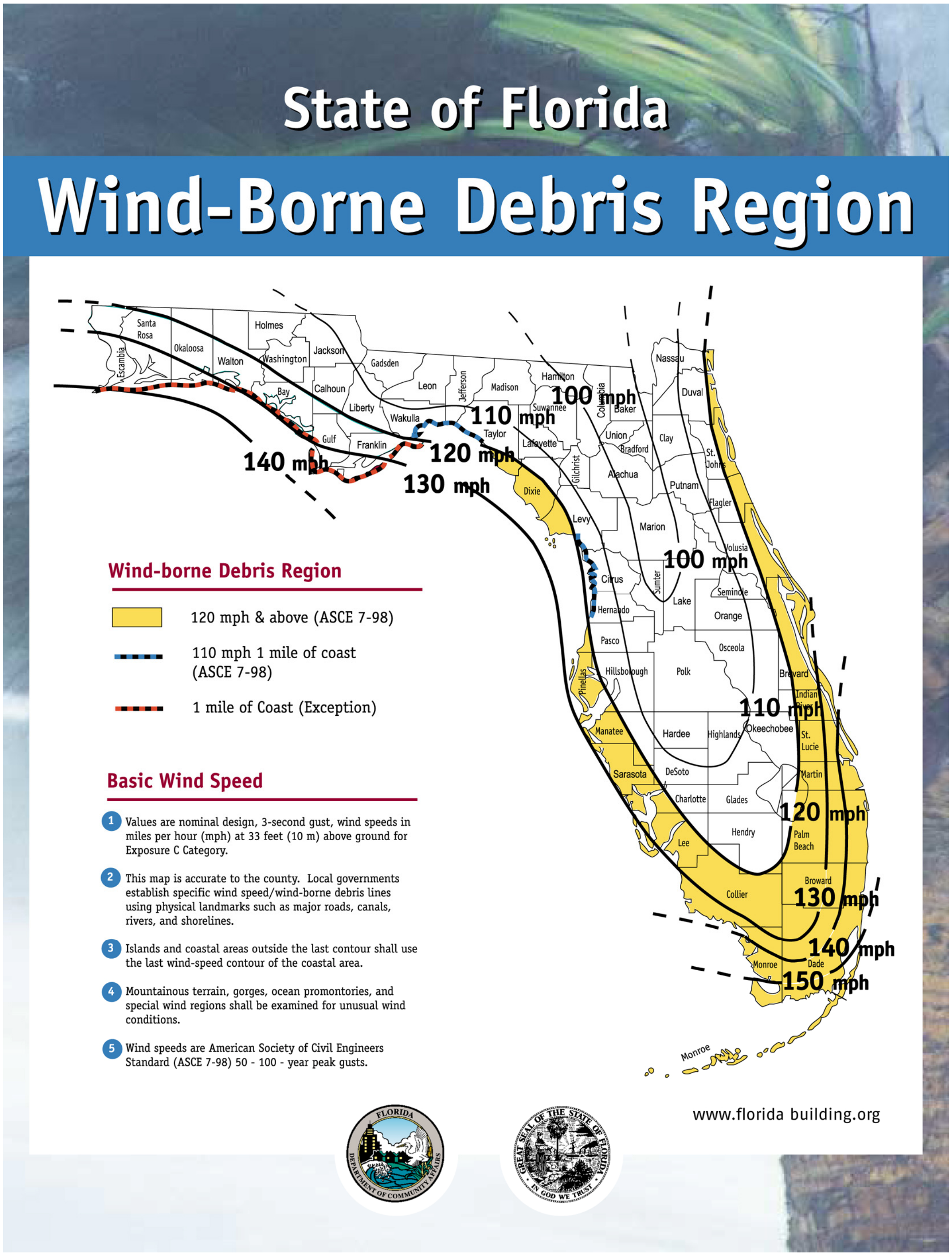
One of the "experimental research product" maps from the NOAA Surface Wind Analysis website (www.aoml.noaa.gov/hrd/Storm_pages) shortly after Ivan made landfall. It shows projected 1-minute sustained wind velocities.

Appendix E. Hurricane Ivan Wind Speed Map



Provided to RICOWI / ORNL by Applied Research Associates, Inc. (ARA), (www.ara.com). This map is essentially an updated version of the preliminary NOAA data. Based on the ARA data, maximum wind gusts at the 70 study sites ranged from 100 to 120 mph.

Appendix F. Florida Wind-borne Debris Map



Map used courtesy of Florida Department of Community Affairs.

Appendix G. Members of Charley Investigation Teams

Hurricane Charley investigation team members (left to right). Kneeling: Lee Shoemaker–Metal Building Manufacturers Association, Pete Croft–Metro Roof Products, Tom Kelly–2001 Company, Patty Wood-Shields–RICOWI, Warren French–French Engineering, Maria Luisa Rouco–School Board of Broward County, André Desjarlais–Oak Ridge National Laboratory, Peter Garrigus–Trufast Corporation, Bas Baskaran–National Research Council of Canada, Art Sark–Rogers & Sark Consulting. Standing: Dave Fulton–Whirlwind Building Systems, Hare Boxall–Metro Roof Products, Bill Young–Florida Solar Energy, Chuck Goldsmith–C. B. Goldsmith & Associates, Ed Ural–Pinnellas County Schools, Robb Smith–Amtech Roofing Consultants, Dave Roodvoets–DLR Consultants, Jerry Vandewater–MonierLifetile, Roger Morrison–North Carolina Foam Industries, Dave Faulkner–Polyfoam Products, Rick Olson–Tile Roofing Institute, unidentified, Joe Wilson–Metro Roof Products, Lonnie Ryder–FEMA, Ross Robertson–Firestone Building Products, Stan Houston–FEMA, Eric Haefli–State Farm Insurance, Ken Hunt–Performance Roof Systems/ARMA, Helene Hardy-Pierce–GAF Materials Corporation/ARMA, Curtis Andrews–FEMA, Ron Kough–Roof Protection Services/GAF, Reese Moody–MonierLifetile, Blair Stephens–Blair Stephens, Ltd., Sal Bucolo–FEMA. Not pictured: Chris Nery–FEMA.

Appendix H. Ivan Investigation Team Members

Ivan investigation team (left to right). Seated: John Goveia—Technical Roof Services, Phil Mayfield—PSM Consultants, Eric Haefli—State Farm, Phil Dregger—RCI/Technical Roof Services, Robb Smith—Amtech Roofing Consultants, Ron Kough—GAF/Roof Protection Services, Patty Wood-Shields—RICOWI. Second row: Jeff Walsh—Magnatrax Corp., Jason Mooney—Metal-Era, Jason Smart—IBHS, Floyd Patterson—Magnatrax Corp., Dave Hunt—Revere Copper Products, Mike Gada—GAF Materials, Maria Luisa Rouco—School Board of Broward County, Tom Kelly—2001 Company. Third row: Lee Shoemaker—Metal Building Manufacturers Association, Joe Wilson—MCA/Metro Roof Products, Dave Roodvoets—SPRI/DLR Consultants, Mike Vaille—CSSB.

Appendix I. RICOWI Information

Background

In 1989, Oak Ridge National Laboratory (ORNL) held two workshops devoted to identifying and discussing roof wind uplift issues and alternatives. Important technical issues that were discussed included

- Dynamic testing of roof systems.
- The importance of sample size for tests.
- The roles of wind tunnels and air retarders.
- The need for acceptable procedures for ballasted systems.
- Field data and response team reports.
- The general lack of communication within the roofing industry as to what the problems are, what is being done and should be done to alleviate them, and how effectively information is transferred within the roofing industry and to others in 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 was approved on October 11, 1990.

In 1996, RICOWI was incorporated as a non-profit corporation devoted to research and education on wind issues. After a review of the need for similar education and research in the areas of hail, energy efficiency, and durability effects, the organization's objectives were broadened in 1999 to include other weather topics; and "Wind" in RICOWI's name was changed to "Weather" to reflect the expanded scope. RICOWI is assisted by ORNL, the banner organization.

Mission

RICOWI is committed to

1. Encouraging and coordinating research to provide a more comprehensive information base on roof issues, including wind, hail, energy efficiency, and durability effects.
2. Accelerating the establishment of new or improved industry consensus standard practices for weather design and testing where they are needed.
3. Improving the understanding of roof weather concepts and issues within the building community in general.

Meetings

RICOWI meetings are held twice a year, in the spring and fall. The spring meeting is usually in conjunction with the spring seminar, which is scheduled to coincide with the Roof Consultants Institute's annual convention. RICOWI meetings are attended by people who are concerned about roofing and weather issues.

The meetings include a business session where the direction and business of RICOWI are discussed, as well as a technical forum. During the latter segment, the Sponsor and Affiliate members have an opportunity to report on the latest developments in their organizations and on technical subjects of common interest. Participants can bring knowledge or concerns to a group of experts who can review ideas, suggest tests or procedures, or provide feedback on the efficacy of proposed designs, approaches, or solutions.

Seminars

Seminars on the proper design, installation and testing procedures for specific roofing materials are held once or twice a year. Fall seminars are usually held at research, testing, or educational facilities and include a tour. They are of interest to roofing professionals, architects, contractors, engineers, facility managers, and those in the insurance industry.

Hurricane and Hail Investigation Programs

RICOWI has implemented two strategic investigation programs:

- Wind Investigation Program (WIP)
- Hail Investigation Program (HIP)

The purpose of the programs is to

- Investigate the field performance of roofing assemblies after major hurricane and hailstorm events.
- Factually describe roof assembly performance and modes of damage.
- Formally report the results for substantiated hurricane/hail events.

The data collected provide unbiased, detailed information on the wind and hail resistance of low slope and steep slope roofing systems from credible investigative teams. The goal is to have a greater industry understanding of what causes roofs to perform or fail in severe wind and hail events. This understanding can lead to overall improvements in roof system durability, reduction of waste generation from re-roofing activities, and a reduction in insurance losses, which may lead to lower overall costs for the public. The reports and multimedia presentations document roofing systems that fail or survive major weather events and provide educational materials for roofing professionals to design wind- and hail-resistant roofing systems. All data are available to be used to improve building codes and roofing design, and to educate the industry and the public.

Wind Investigation Program

Subsequent to RICOWI's formation, other concerns were raised. The insurance industry conveyed its concern regarding excessive property loss from wind damage. Industry experts estimated that from 1986 to 1995, hurricanes and high winds have accounted for 78% of catastrophic losses. Estimated insured losses from hurricanes have averaged $10 billion per year since 1989. In August 1992, Hurricane Andrew caused $16 billion in insured losses in South Florida. Several other hurricanes have hit the South Florida area since Andrew, resulting in catastrophic losses.

There is an essential link between product research, performance, and the model building codes. The model code groups are moving more toward "performance-based codes" versus "prescriptive codes." Performance requirements are generally perceived to be requirements stated in a way that allows flexibility in the choice of solutions to satisfy the requirements. As such, they are based upon explicit objectives. Code changes are being adopted by the model code groups without adequate industry input. In addition, there is a general feeling that the right type of data have not been gathered following events.

There is no question that all roofing products and systems of all roofing associations must meet more rigorous requirements. These products and systems will be subject to tougher scrutiny by building departments, as we have already seen in Dade and Broward counties in Florida. Industry involvement in follow-up of wind events is imperative.

RICOWI and the U.S. Department of Energy (DOE)/ORNL responded to these concerns by entering into a cooperative research and development agreement (CRADA) to facilitate the WIP. The Program includes all of the major roofing trade associations in North America.

This Program will put credible people in the field who have the required product knowledge and program training to ensure that sound, scientific, and unbiased reporting occurs. RICOWI's goal is that buildings will be safer, property losses will be reduced, and the industry will meet the challenge with clear insight as to the needed direction. The reports generated by our investigation teams and findings will be used to help educate, as well as to improve products, installation techniques, and safety. They should also reduce overall roofing and insurance costs for the industry, as well as providing a valuable resource to the Federal Emergency Management Agency and state emergency management agencies.

CRADA and U.S. Government Participation

In 1996 RICOWI entered into a CRADA with UT-Batelle, LLC (the contractor that manages ORNL) under the auspices of DOE. The CRADA is jointly funded by DOE's Energy Efficiency and Renewable Energy, Office of Building Technology, state and community sector programs, and industry partners. The sponsoring associations supplied other major funding, and their individual companies provided in-kind funds to support the CRADA by covering inspectors' costs for travel and labor.

The scope of work under the CRADA is to investigate and report the field performance of low slope and steep slope roofing systems after major hurricanes [i.e., those with sustained wind speeds of 95 mph (1 minute sustained) or greater] make landfall on the continental United States in populated areas.

ORNL has been working with private industry to accelerate the acceptance of more energy-efficient and durable roofing systems. ORNL facilitated the training and issuance of identification badges for RICOWI team members.

Following this report will be the development of educational tools illustrating how to design and construct more durable and energy-efficient roofs, and pointing out the consequences of falling short. A profile will be developed as to the performance of various roofing systems in severe wind events, leading to overall improvement in roof system durability, the reduction of waste generation from re-roofing activities, and a reduction in insurance losses. These should lead to lower overall costs for the public.