AN ASSESSMENT OF DAMAGE TO MANUFACTURED HOMES CAUSED BY HURRICANE CHARLEY



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Disclaimer

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Summary

On August 13, 2004, the Southwestern Gulf Coast of Florida was struck by Hurricane Charley. HUD quickly assembled a team to assess the performance of manufactured homes and to make any recommendations for continued improvement.

Even though the winds of Hurricane Charley did not generally reach the maximum design wind requirements, this study provided significant information regarding the performance of manufactured homes produced after July 13, 1994, when the revised wind load requirements became effective, as compared to the homes produced under the previous standards. This study helped to assess the effectiveness of Florida's revised installation requirements (effective March 29, 1999), the effectiveness of field installation of siding, and the effect of add-ons on the performance of homes. The evaluation team did not find any home sited on permanent foundations designed in accordance with HUD permanent foundation guidelines for manufactured housing.

Conclusions are as follows:

1. The wind pressures on the manufactured homes in the sample area were approximately 50% to 75% of the design load for homes produced after July 13, 1994 based on the updated HUD code.

2. Post July 13, 1994 homes performed significantly better than Pre-1994 homes at a high level of confidence. Furthermore, pre-HUD homes were much more severely damaged than newer (post 1976) HUD Code units at a high confidence level. This significant trend of improvement was evident in all areas related to the scope of the HUD Code, from roof construction to roof-to-wall connections, to walls and overall structural integrity.

3. Newer foundation installations installed under Florida's revised (1999) Installation Standards typically performed with a relatively low level of damage. However, Post-99 foundation installations were not flawless, and about 40 percent experienced some level of damage (e.g. slipping on piers and damage to vinyl skirting). In addition, modest amounts of scour and undermining of shallow piers due to wind and rain water run-off were noted in some cases.

4. Florida's installation requirements do not establish any performance standards for skirting. In general, there was significant damage to the skirting.

5. Field installation of siding was not as effective as factory installation. In addition, the corners and edges of homes showed a higher general degree of damage than other points of homes.

6. Add-ons such as screened porches, carports and garages generally performed very poorly across all age groups of construction. In most instances, the connections of these add-ons failed, resulting in damage to the home. Aluminum roofing from add-on construction was a common source of wind-borne debris.

7. Tie-down straps were frequently observed to be corroded and rusted. The corrosion may have been accelerated when the straps were embedded in concrete or were in direct contact with ground moisture.

8. Even though not specifically documented, the homes with shutters generally sustained less damage than those without window protection.

9. The evaluation team did not find any homes sited on permanent foundations designed in accordance with HUD permanent foundation guidelines for manufactured housing.

Introduction

On Friday, August 13, 2004, the Southwestern Gulf Coast of Florida was struck by Hurricane Charley, with a maximum over-land wind speed of approximately 110 mph (sustained) and less in highly developed areas of Punta Gorda, Port Charlotte, and surrounding communities. Correspondingly, maximum gust wind speeds are estimated to be 130 mph or less in open overland exposure; an anemometer measurement from the Punta Gorda Airport registered a wind gust of 111 mph, but failed prior to complete passage of the event (NOAA, August 16, 2004). For the region defined by the representative sample of manufactured homes investigated in this study, typical wind speeds are estimated to be in the range of 90 to 110 mph (sustained) at 33 feet from the ground. See the *Event Characterization* section of this report for further details.

While these wind speeds suggest that Hurricane Charley was a strong Category 2 or marginal Category 3 event in terms of its general impact to inland coastal regions and major developed areas, its over-water wind speed at or just prior to initial landfall was reported to be approximately 140 mph (1-minute sustained) – a Category 4 hurricane according to the Saffir-Simpson scale. Data from the National Oceanic and Atmospheric Administration's Hurricane Research Division regarding the magnitude of Hurricane Charley's winds as they changed during landfall and during its track inland are discussed later in this report. In general, however, it will be some time before consensus is reached among experts to arrive at a consistent and scientifically agreed upon characterization of Hurricane Charley's wind field.

Because the hurricane track prediction was abruptly altered only a matter of hours before a mid-evening landfall, residents had limited time to make final preparations and to evacuate. In Punta Gorda, Port Charlotte, and surrounding communities that were hardest hit by Hurricane Charley, damage was severe, resulting in widespread power outage, debilitation of emergency services, loss of life, and large economic losses.

The affected region and communities have a relatively large population of manufactured housing units that serve affordable housing needs ranging from newer upscale owner-occupied communities to older rental-based manufactured housing parks. Because of the importance of manufactured housing, and for other reasons related to its safe regulation in hurricane-prone regions of the United States, the Office of Manufactured Housing Programs of the U.S. Department of Housing and Urban Development (HUD) commissioned this study to assess the damage to manufactured homes. This study follows an objective damage assessment methodology, making statistical analysis of a representative sample of manufactured homes and their performance in Hurricane Charley possible. Such an approach should lead to a better understanding of past decisions, while giving objective guidance for future decision making, as has been demonstrated in prior studies of a similar nature for HUD (McKee and Crandell, 1999; Crandell and McKee, 2000). Statistical findings of this report are also supplemented with important damage observations that are more anecdotal in nature.

While this study permits broad characterizations of the sampled manufactured housing population and its performance, it was intended to provide information related to a few “high priority” issues. Specifically, three key questions were posed for the study:

1. Did newer manufactured housing units (i.e., Post-1994) perform better than older units (i.e., Pre-1994)? HUD Code standards were initiated in June 1976 and updated in July 1994 to improve wind performance based on the experience the Department gleaned from Hurricane Andrew in 1992.

2. Did newer (i.e., post-1999) Florida requirements for foundations and anchorage of manufactured homes perform adequately in comparison to the HUD requirements for permanent foundations that enable Title II financing (e.g., 30-yr mortgage) for manufactured housing?

3. Did the winds of Hurricane Charley produce loads similar to those required in the HUD Code, such that homes built to the newer HUD Code requirements and Florida foundation requirements were fully “tested” by the event?

Sufficient data was collected to provide a statistically conclusive answer to the first question. Observations and data obtained during the survey also provide guidance regarding the above questions, in addition to several other findings. Unfortunately, no manufactured homes on permanent foundations (HUD, 1996) were found in the study region. Therefore the study produced insufficient information to make a direct comparison between performance of HUD permanent foundations and newer Florida foundation installation and anchorage requirements. However, a number of newer Florida foundations were sampled in the study to allow an assessment of their performance.

This report is organized to first provide background information regarding hurricanes, wind, and manufactured housing regulations. The background section is intended to provide a proper context and a level of understanding necessary to best interpret the findings of this study. The background information is followed by a section devoted to characterizing Hurricane Charley and the estimated wind loads experienced by the sampled manufactured homes of this study.

Next, construction characteristics and damage statistics are presented and discussed in a section titled Damage Assessment. In addition, results of statistical inferences regarding the performance of different construction age groups and construction characteristics are provided. Supplemental observations follow in sequence, to address important items not specifically addressed in the statistical damage assessment analyses. The report closes with sections providing conclusions and recommendations.

Background

Classification of Hurricanes

The accepted method of classifying hurricanes is the Saffir-Simpson Scale, which serves as a rough or subjective measure of potential for damage. Hurricanes are categorized into five classes (Table 1) based primarily on the atmospheric pressure depression within the eye of the hurricane. In Table 1, the central eye pressure is also associated with an expected range of maximum wind speed and storm surge. Hurricane Charley's central pressure at or near the time of landfall was 946 mb, with a sustained surface level wind speed estimated to be 123 knots (141 mph) as shown later in Figure 1. Thus, according to central pressure, Hurricane Charley may be classified as a Category 3 hurricane, but by estimated surface winds it may be classified as a Category 4 hurricane at its peak. This contradiction demonstrates the difficulty in uniformly classifying hurricanes and relating them to a subjective description of damage potential.

Table 1
Classification of Hurricanes
By the Saffir-Simpson Damage Potential Scale

Category	Central (Eye) Pressure, mb*	Winds, mph**	Surge, ft.	Potential Damage
1	≥ 980	74 – 95	4 - 5	Minimal
2	965 - 979	96 – 110	6 - 8	Moderate
3	945 - 964	111 – 130	9 – 12	Extensive
4	920 - 944	131 – 155	13 - 18	Extreme
5	< 920	> 155	> 18	Catastrophic

* Standard atmospheric pressure at sea level is about 1013 mb (14.7 psi).
** Maximum sustained (1-minute) wind speed at an elevation of 10 meters (33 feet).

It is useful to compare Hurricane Charley to other storm events for which similar damage assessment studies have been conducted. Hurricane Andrew, recently reclassified by NOAA as a Category 5 hurricane, with sustained wind speeds of more than 155 mph over sea and about 145 mph extending well inland, caused extensive wind damage resulting in at least some amount of lost roof sheathing for 70% of the homes in the area (Crandell, 1993; Crandell, 1998). However, relatively little damage was caused by the storm surge. Conversely, Hurricane Opal had a maximum gust wind speed of about 125 mph at landfall, which corresponds to a sustained wind speed of about 102 mph and a Category 2 on the Saffir-Simpson Scale. Wind damage was moderate in that about 2% of sampled homes had some amount of roof sheathing damage or loss (Crandell, 1996). Unfortunately, Opal's storm surge did extensive damage to many older (unelevated) beach front homes. Other damage characteristics, such as roofing damage or even tree damage, may also be used as a comparative index to determine the relative wind speed and damage potential of events. In general, observed damage from Hurricane Charley appears to fall well below that of Hurricane Andrew, but slightly above that of Hurricane Opal. Therefore, after the time of initial landfall and particularly for some distance inland in populated areas such as Punta Gorda and Port Charlotte, the wind field of Hurricane Charley may be more reflective of a marginal Category 3 event.

Wind Characteristics

Wind is a highly variable natural phenomenon. Therefore, the magnitude of a wind speed measurement depends on the averaging time over which the measurement is made. As mentioned, hurricanes are generally classified and reported on the basis of a maximum sustained wind speed, meaning an average wind speed observed over a 1-minute interval. While older wind engineering standards and building codes have used the fastest-mile wind speed (based on the average speed of a 1-mile length of wind passing an anemometer), newer wind engineering standards use a gust wind speed basis which is generally considered to have a much shorter averaging time of 3 seconds or less. Truly instantaneous wind speed measurements are difficult if not impossible to make.

It is important to know and understand the averaging time associated with a particular reported wind speed. To assist in this understanding, Table 2 provides typical wind speed conversions between different averaging times for wind speed measurements. For example, Hurricane Charley may be reported at about the time of landfall to have a sustained wind speed of 140 mph, a fastest-mile wind speed of 151 mph, or a gust wind speed of 170 mph. All are theoretically correct; they only differ in the amount of averaging of the "peaks and valleys" that occur in any wind record over a specified time period. In addition to the averaging time conversions, wind speeds are often reported in nautical terms, such as knots. One knot is equal to 1.15 mph. Thus, both unit conversions and averaging time conversions may be necessary to make an "apples-to-apples" comparison of reported wind speeds. Finally, wind speeds are affected by the exposure condition (surface roughness) and elevation above ground level upon which they are based. Therefore, if elevation or exposure differences exist in reported wind measurements, these also need to be normalized to allow for a consistent comparison.

Table 2
Conversion of Wind Speeds
For Various Units and Averaging Times
Used to Report Wind Measurements

Wind Speed Basis	**Equivalent Wind Speed Magnitudes**								
3-second gust (mph)	90	100	110	120	130	140	150	160	170
Fastest-mile (mph)	76	84	93	103	114	123	132	141	151
Sustained (mph)	74	82	90	99	107	115	123	132	140
Sustained (knots)	64	72	79	86	93	100	107	115	122

Table Notes:
1. Because wind is a highly variable natural phenomenon, the above relationships are considered as typical, but may vary for any given wind record.
2. Conversions are based on the "Durst Curve" (ASCE 7-02, Figure C6-2). For example, the ratio of sustained to 3-second gust wind speed from the Durst Curve is 1.25/1.53 = 0.82. Therefore, 100 mph 3-second gust wind speed is equivalent to an 82 mph sustained wind speed as shown in the table. Other conversions were made in a similar fashion.

Moving air or wind, when obstructed, must flow around the obstruction. Depending on the shape and size of the obstruction and the speed, density, direction, and turbulence of the wind, regions of low and high pressure are created on the upwind (windward) and downwind (leeward) surfaces of the obstruction. Negative or suction pressures act outward from the surface of the obstruction, and are generally found on leeward building surfaces and immediately downstream from abrupt changes in geometry (e.g., a roof eave or wall corner on the windward face of the building, shown in Appendix E, Figure 7.32). Positive or inward acting pressure acts only on the upwind or windward faces of the building, and is due to stagnation of wind impinging on the obstruction. Needless to say, wind and its load effects involve theoretically complex processes, especially when the dynamic nature of wind is considered.

As a matter of research and public interest, wind tunnel studies of manufactured housing and other low-rise types of construction have been done (Ho, 1992; Gurley et al., 2003; St. Pierre, et al., 2003). These studies indicate the significant effect of obstructions such as adjacent buildings (even if only one or two rows in the upwind direction) that generally reduce wind loads on downwind structures to a degree not fully considered in current wind engineering standards. In short, proper consideration of wind exposure for a given site, as well as the nature of a reported wind speed, are necessary to accurately estimate actual wind loads for a given site and wind event or to prescribe reasonable design loads for the purposes of building regulation.

In addition to external pressures created by wind flowing around a building, internal pressures are present depending on the level of porosity of a given building. In general, buildings are somewhat porous. Therefore, pressures on the external surface will affect pressures on the interior of a building. When a building's envelope is compromised, by loss of a door or breakage of a window on the windward side of the building, for example, internal pressurization occurs. Elevated internal pressures increase the potential for roof blow-off and other types of wind damage. Therefore, the degree to which a building envelope is protected against failure will affect the amount of wind load that the building structure is likely to experience. If a building envelope remains enclosed (e.g., no loss of windows or doors), lower internal pressures are experienced, and structural damage is less likely to occur. Modern wind load standards require that internal pressurization and envelope protection be considered as a part of determining design wind loads in hurricane-prone regions.

Standard 3280.403(f) contains the following language with regard to shutters:

> *Protection of primary window and sliding glass door openings in high wind areas. For homes designed to be located in Wind Zones II and III, manufacturers shall design exterior walls surrounding the primary window and sliding glass door openings to allow for the installation of shutters or other protective covers, such as plywood, to cover these openings. Although not required, the Department encourages manufacturers to provide the shutters or protective covers and to install receiving devices, sleeves, or anchors for fasteners to be used to secure the shutters or protective covers to the exterior walls. If the manufacturer does not provide shutters or other protective covers to cover these*

openings, the manufacturer must provide to the homeowner instructions for at least one method of protecting primary window and sliding glass door openings. This method must be capable of resisting the design wind pressures specified in 3280.305 without taking the home out of conformance with the standards in this part. These instructions must be included in the printed instructions that accompany each manufactured home. The instructions shall also indicate whether receiving devices, sleeves, or anchors, for fasteners to be used to secure the shutters or protective covers to the exterior walls, have been installed or provided by the manufacturer.

[52 FR 4583, Feb. 12, 1987, as amended at 52 FR 35543, Sept. 22, 1987; 58 FR 55009, Oct. 25, 1993; 59 FR 2474, Jan. 14, 1994.]

Discussion of 1994 Changes in the Manufactured Home Wind Standards

As a result of Hurricane Andrew, which struck South Florida on August 24, 1992, there was considerable damage to all kinds of housing, manufactured homes in particular. There were many studies conducted to assess the damage caused by Hurricane Andrew, and to suggest ways to improve the construction of homes in order to minimize future damage. As a result of these studies, HUD published a rule amending the Federal Manufactured Homes Construction and Safety Standards (FMHCSS) on January 14, 1994 (59 FR 2456) in order to improve the resistance of manufactured homes to wind forces in areas prone to hurricanes. An Interpretive Bulletin was issued on April 15, 1994 and published in the Federal Register on April 21, 1994. Another interpretive bulletin was issued on July 1, 1994 (59 FR 126), which established, among other things, the effective date of the revised wind standards as July 13, 1994.

The FMHCSS was modified in many areas to incorporate all the changes required due to revised wind requirements.

According to Sections 3280.305 A and B of *Part 3280, Manufactured Home Construction and Safety Standards and Interpretive Bulletins to the Standards,* issued by the United States Department of Housing and Urban Development:

The design wind loads for Exposure C specified in ANSI/ASCE 7-88, "Minimum Design Loads for Buildings and Other Structures," for a fifty year recurrence interval, and a design wind speed of 100 mph, as specified for Wind Zone II, or 110 mph, as specified for Wind Zone III (Basic Wind Zone Map).

Florida's Anchorage and Installation Requirements

On March 29, 1999, the State of Florida implemented revised anchorage and installation requirements. See the Rules of the Department of Highway Safety and Motor Vehicles Mobile/Manufactured Home Installation Standards, Chapter ISC-1 and ISC-2. These chapters establish a minimum anchor load resistance capacity as well as horizontal and vertical tiedown requirements. The State of Florida also increased the galvanization of the tiedown straps from what had previously been required by the Federal Manufactured Home Construction and Safety Standards (FMHCSS).

According to the Florida Standards, the anchors and the stabilizing devices require hot dipped zinc galvanizing (.60 ounces per square foot) while the straps require hot dipped zinc galvanization at the rate of 1.20 ounces per square foot.

Hurricane Charley

Event Characterization

In preface to this section, any wind speeds reported herein should be considered as preliminary and subject to change as additional data and/or modeling results become available. As shown in Figure 1, the maximum wind speed of Hurricane Charley at approximately the time of landfall was reported to be about 123 knots (141 mph) as a sustained, 1-minute average wind speed at an elevation of 10 m (33 feet) over open water. According to the Saffir-Simpson scale, Hurricane Charley was reported as a Category 4 hurricane at or just prior to landfall.

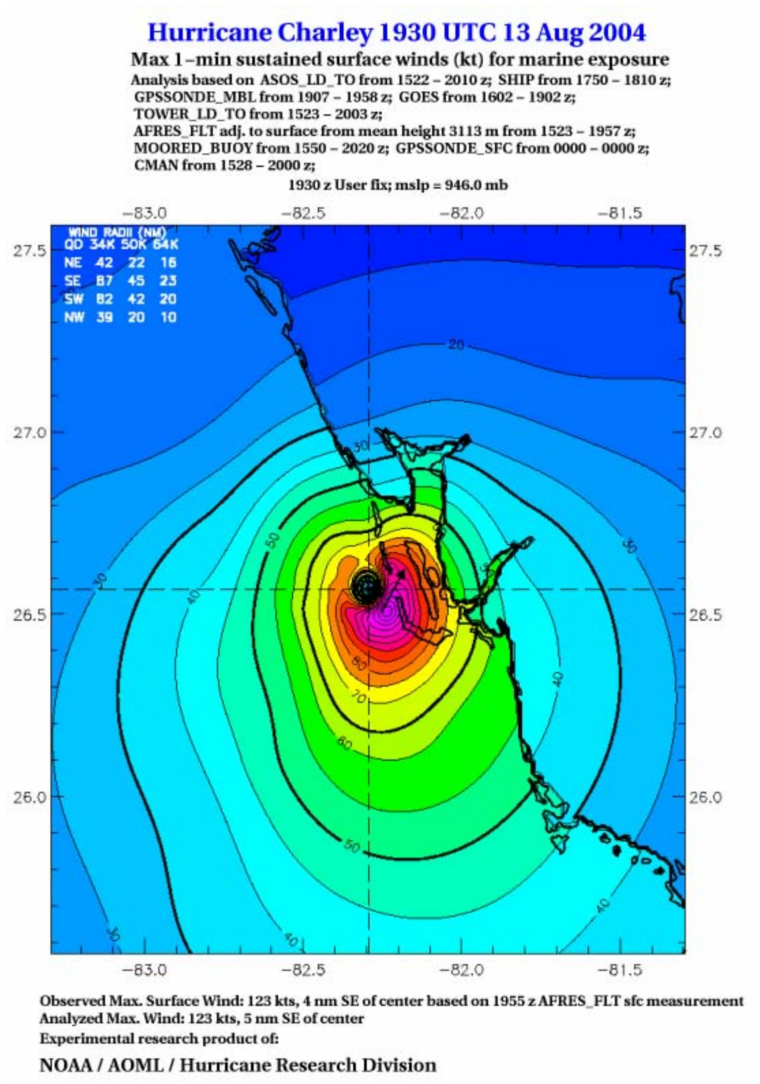


Figure 1. Hurricane Charley Wind Field at Landfall

[Knots, 1-min sustained, over sea exposure, 10 m elevation]

Above image provided by the Hurricane Research Division (HRD) of the National Oceanic and Atmospheric Administration (NOAA) (www.aoml.noaa.gov/hrd/data/registration.html).

The surface roughness of the land and other factors significantly degraded wind speeds near the ground, as Hurricane Charley tracked inland across Punta Gorda, Port Charlotte, and areas farther inland (see Figure 2). Therefore, maximum overland wind speeds in these areas and the extended region from which manufactured housing was sampled for this study appears to have ranged from about 90 to 110 mph (1-minute, sustained) at an elevation of 10 m (33 feet) over an assumed "open" inland exposure (see Figure 2). Considering the gustiness of wind that is not represented in sustained wind speed measurements, the 3-second gust wind speeds experienced over the study region may be roughly characterized as ranging from about 110 to 130 mph (based on the "Durst Curve" from ASCE 7-02 Figure C6-2 and assuming open terrain). In terms of an older representation of wind speed known as fastest-mile wind speed, the estimated fastest-mile wind speeds over the study area ranged from about 93 mph to 114 mph. The wind swath of Figure 2 is based on methods used by the Hurricane Research Division of NOAA (Powell, Houston, and Reinhold, 1996; Powell and Houston, 1996). Based on Figure 2, a typifying wind speed for the study region and sampled homes in general is approximately 100 mph (fastest-mile).

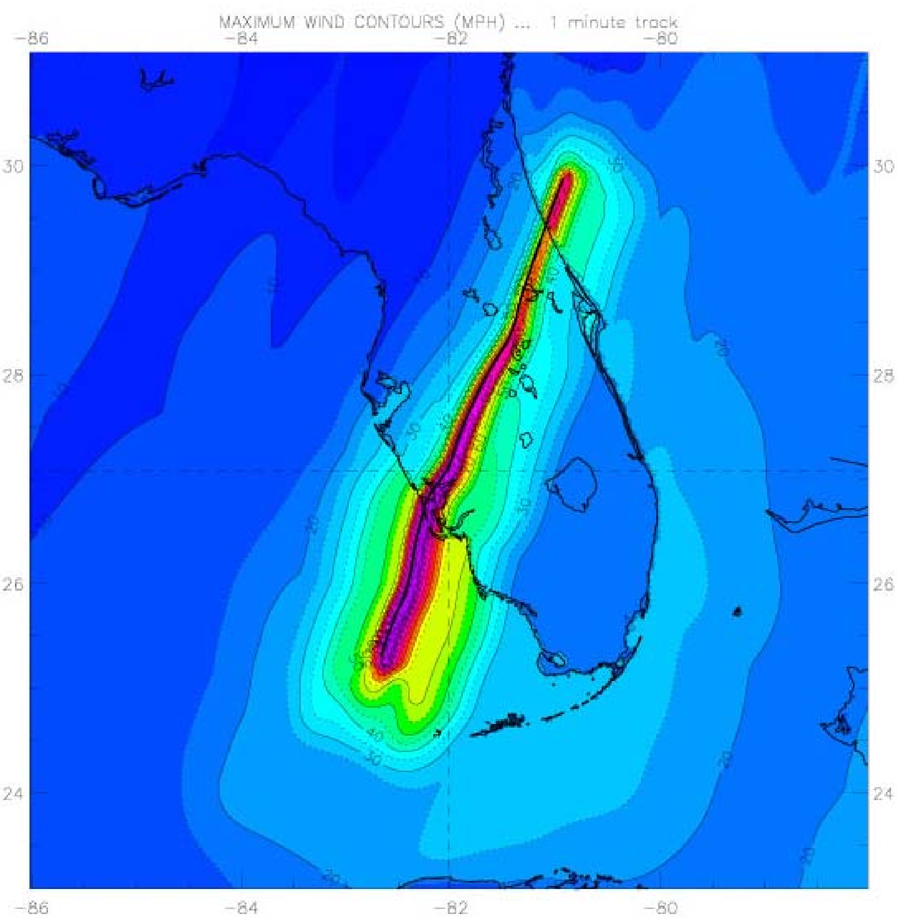


Figure 2. Maximum Wind Speed Contours for Hurricane Charley's Track [MPH, 1-minute sustained, over-sea or over-land exposure, 10 m elevation]

Above image provided by the Hurricane Research Division (HRD) of the National Oceanic and Atmospheric Administration (NOAA) (www.aoml.noaa.gov/hrd/data/registration.html).

Because the inland wind exposure of the sampled manufactured housing stock was primarily built-up due to surrounding development, and often included trees that survived the event, actual near-ground wind speeds may be further reduced. Estimating wind speeds near to the ground surface and within the layer of surface roughness is beyond the scope of this report, even though the issue is quite relevant. The reader is referred to other studies which discuss methods for estimating near-ground wind speeds in suburban and/or wooded terrain conditions (Crandell, et al., 2000). Site exposure considerations are very important to the proper characterization of wind loads on buildings and are addressed in the next section of this report.

Estimated Wind Loads

Wind loads for building designs have evolved over time, and will continue to evolve as better information and scientific knowledge is put to use. At the time the HUD Code was updated in 1994, the ASCE 7-88 standard (ASCE, 1988) was used as the basis for wind loads as shown in Table 3. The wind loads are based on an open site exposure condition. In addition, the wind map in ASCE 7-88, which displayed fastest-mile design wind speeds, was used to create wind zones as shown in Figure 3.

TABLE 3
HUD Code Wind Pressures

TABLE OF DESIGN WIND PRESSURES

Element	Wind zone II design wind speed 100 MPH	Wind zone III design wind speed 110 MPH
Anchorage for lateral and vertical stability (See §3280.306(a)):		
Net Horizontal Drag[1,2]	[3]±39 PSF	[3]±47 PSF
Uplift[4]:	[5]−27 PSF	−32 PSF
Main wind force resisting system:		
Shearwalls, Diaphragms and their Fastening and Anchorage Systems[1,2]	±39 PSF	±47 PSF
Ridge beams and other Main Roof Support Beams (Beams supporting expanding room sections, etc.)	−30 PSF	−36 PSF
Components and cladding:		
Roof trusses[4] in all areas; trusses shall be doubled within 3'–0" from each end of the roof	[5]−39 PSF	[5]−47 PSF
Exterior roof coverings, sheathing and fastenings[4,6,7] in all areas except the following	[5]−39 PSF	[5]−47 PSF
Within 3'–0" from each gable end (overhang at end wall) of the roof or endwall if no overhang is provided[4,6,7]	[5]−73 PSF	[5]−89 PSF
Within 3'–0" from the ridge and eave (overhang at sidewall) or sidewall if no eave is provided[4,6,7]	[5]−51 PSF	[5]−62 PSF
Eaves (Overhangs at Sidewalls)[4,6,7]	[5]−51 PSF	[5]−62 PSF
Gables (Overhangs at Endwalls)[4,6,7]	[5]−73 PSF	[5]−89 PSF
Wall studs in sidewalls and endwalls, exterior windows and sliding glass doors (glazing and framing), exterior coverings, sheathing and fastenings[8]:		
Within 3'–0" from each corner of the sidewall and endwall	±48 PSF	±58 PSF
All other areas	±38 PSF	±46 PSF

NOTES:

[1]The net horizontal drag of ±39 PSF to be used in calculating Anchorage for Lateral and Vertical Stability and for the design of Main Wind Force Resisting Systems is based on a distribution of wind pressures of +0.8 or +24 PSF to the windward wall and −0.5 or −15 PSF to the leeward wall.

[2]Horizontal drag pressures need not be applied to roof projections when the roof slope does not exceed 20 degrees.

[3]+ sign would mean pressures are acting towards or on the structure; − sign means pressures are acting away from the structure; ± sign means forces can act in either direction, towards or away from the structure.

[4]Design values in this "Table" are only applicable to roof slopes between 10 degrees (nominal 2/12 slope) and 30 degrees.

[5]The design uplift pressures are the same whether they are applied normal to the surface of the roof or to the horizontal projection of the roof.

[6]Shingle roof coverings that are secured with 6 fasteners per shingle through an underlayment which is cemented to a 3/8" structural rated roof sheathing need not be evaluated for these design wind pressures.

[7]Structural rated roof sheathing that is at least 3/8" in thickness, installed with the long dimension perpendicular to roof framing supports, and secured with fasteners at 4" on center within 3'–0" of each gable end or endwall if no overhang is provided and 6" on center in all other areas, need not be evaluated for these design wind pressures.

[8]Exterior coverings that are secured at 6" o.c. to a 3/8" structural rated sheathing that is fastened to wall framing members at 6" on center need not be evaluated for these design wind pressures.

NOTE – All units surveyed were in Charlotte or Lee Counties; therefore Zone III .

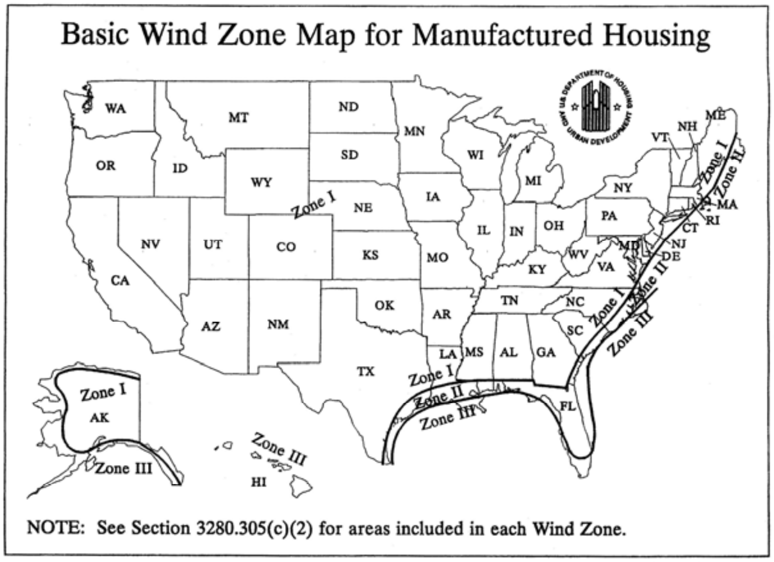


Figure 3. Wind Zones for HUD Code Based on ASCE 7-88
Fastest-Mile Design Wind Speed Map
(Zone III = 100 mph or greater; Zone II = 90 mph to 100 mph; Zone I = less than 90 mph).

The Punta Gorda/Port Charlotte area falls in Zone III. All homes sampled were in Charlotte and Lee Counties (see Appendix B). The areas where the manufactured homes were sampled were all in Exposure B, with a typical fastest-mile wind speed of 100 mph, estimated (93-114). The wind pressures on the sampled manufactured homes were therefore roughly 50% (mph) of the HUD Code design Main Wind Force Resisting System wind loads and anchorage loads. The components and cladding wind pressures were approximately 75% of the HUD Code design loads.

> These estimates are based upon the factors in the ASCE 7-88 Standard that account for the effect of wind speed and terrain roughness on wind load in comparison to the design wind speed and exposure condition used to develop the wind loads in the HUD Code. The 50% value is derived from V, K_Z, and G values in ASCE 7-88 for main wind force loads as follows: (K_B/K_C) x (G_B/G_C) x (V_{Actual}/V_{Design})squared = (0.37/0.8) x (1.65/1.32) x (100/110)squared = 0.5, or 50% of the HUD Code design Main Wind Force Resisting System wind loads. The 75% value is derived in similar fashion, and pertains to components and cladding loads.

Damage Assessment

Methodology

This damage assessment study of manufactured housing followed a scientific method of sampling and documenting building characteristics and performance. The methodology is similar to that used in previous studies of site-built housing construction following major hurricane, tornado, and earthquake events (Crandell, 1993; Crandell, 1994; Crandell, 1996; Crandell, 1998; Crandell, 2002). A survey form to document housing characteristics and damage was adapted for use with manufactured housing based on similar forms used in the prior studies for site-built housing. The survey form is shown in Appendix A. This approach was taken to allow a comparable data collection and analysis effort.

Two teams of two to three individuals each conducted the survey following a sampling methodology intended to obtain a representative sample of the manufactured housing stock within three age categories of interest (i.e., Pre- and Post-1994 HUD Code units and Pre-1976 non-HUD Code units). Wherever feasible, specific observations were made related to the performance of the foundation system for homes installed after March 29, 1999. The purpose of these observations (case studies) was to assess the impact of the revised Florida installation standards on the overall performance of the manufactured homes.

Damage was co-rated on an initial sample at the beginning of the survey to calibrate the teams to a consistent rating methodology. The damage rating methodology is described in Table 4 and corresponds to only the top portion of page 3 of the damage survey form (Appendix A). It is very important to the proper interpretation of results given later in this study. Other survey form entries related to site or building characteristics do not require explanation.

TABLE 4
Damage Rating Criteria

Damage Category	Damage Levels			
	0	**1**	**2**	**3**
Roof System	No observed damage	Exterior finish damage only	Localized structural damage (e.g., sheathing or gable damage)	Partial or full roof loss
Wall System	No observed damage	Exterior finish damage only	Localized structural damage without collapse	Partial or full collapse of walls
Foundation System	No observed damage	Minor shifting on foundation (i.e., less than ½") or damage to skirting	Significant shifting on foundation, but still on piers	Foundation shifted off of piers or rolled over
Projectile	No observed damage	Few wall impacts or broken windows	1/3 to 2/3 of glass broken and many wall impacts damaging siding and/or sheathing	Damage from many small projectiles or a large impact causing structural failure
Add-on (e.g., porches and carports)	No observed damage	Exterior finish damage only, but structural in tact	Partial destruction	Near to complete destruction

Table Notes:
1. Rating is based on observable damage; therefore, damage classification is subject to some degree of observational error and variance.

Figure 4.1: An Example of Level 3 Roof System and Level 2 Wall System Damage [Note: In this case, the roof rating was primarily associated with extensive roof sheathing loss; the wall rating was based on some localized structural damage to sheathing in addition to extensive siding damage, even though the walls were essentially structurally intact.]

Figure 4.2: An Example of Level 3 Add-On Damage

Figure 4.3: An Example of Level 1 Wall System Damage
[Note: Damage was limited primarily to wall finishes, i.e. vinyl siding damage]

While the survey form served its purpose, experience during the survey and data entry processes indicates that the form could be improved to facilitate faster and more precise data collection and evaluation. For example, each data entry item should include all possible results to be checked by the assessor (such as indicating whether or not an item is "unknown"). As a rule, items that could not be directly confirmed by observation were either left blank or noted as "unknown" on the survey forms. Thus, for certain characteristics or damage ratings, the sample size may vary to some number less than the total number of units inspected. This outcome is particularly relevant to concealed building characteristics (such as roof or wall sheathing or stud size and spacing), because in many cases damage was not sufficient to allow a non-destructive visual observation to be made.

Samples of manufactured homes were selected from 12 of 17 different manufactured housing developments visited in the region affected by the highest winds of Hurricane Charley (see Figure 4.5 and Table 5). The study region extended from Pine Island at the gulf coast to just north and east of Punta Gorda and Port Charlotte on Route 17. From each study location, one or two representative streets were pre-selected, and the first and every third or fourth home thereafter were sampled on one side of each selected street.

One of the teams did not include homes in its sample where it was evident that the home in question had been manufactured prior to the implementation of the FMHCSS.

The study was conducted over the course of 3½ days, approximately one week after the event (August 18-21, 2004).

Figure 4.5: Approximate Location of Manufactured Housing Study Sites

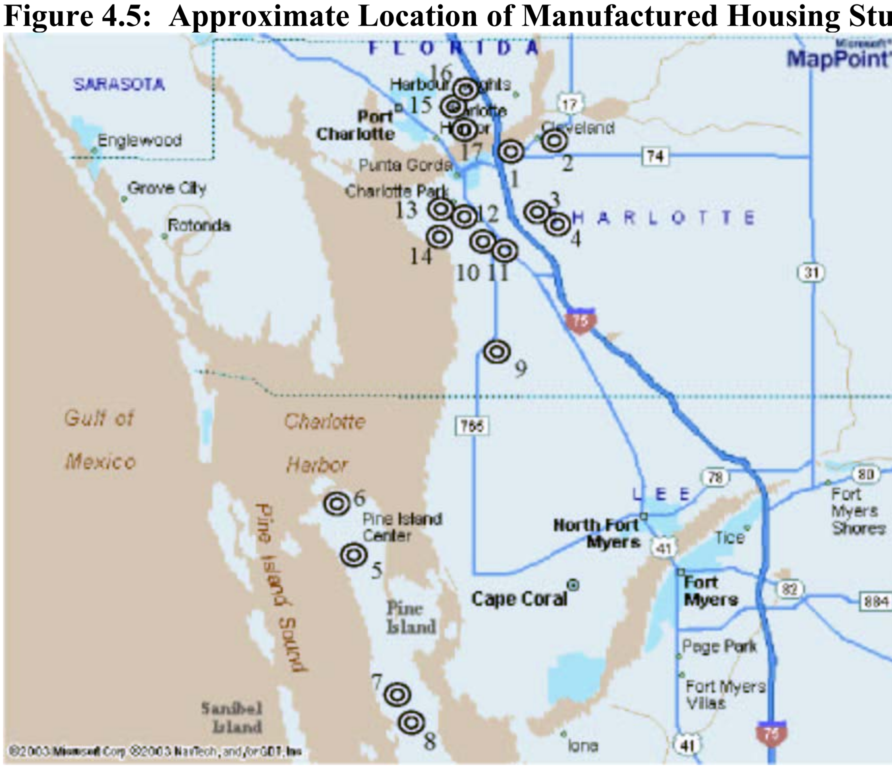


TABLE 5
Distribution of Manufactured Home Samples
By Study Site Location

Study Site ID	1	2	3	4	5	8	9	12	13	14	16	17	TOTAL
Number of Samples (n)	14	12	6	8	6	4	6	10	13	18	7	1	105

1. Study site ID numbers correspond to Figure 5.5. Study sites not listed in this table had no samples.

In cases where newer (Post-1994) homes were encountered during the survey, these homes were included in the sample whether or not they were selected following the randomized procedure. This sampling variation was done to ensure a suitable sample size of newer homes and to also provide a direct case study of newer homes in close proximity to older homes. Lack of staged sampling within age groups of construction was found to be a drawback of a completely randomized sampling across all ages of construction. Thus, earlier statistical damage studies tended to adequately represent the performance of older construction (i.e., 1950s to 1970s era housing) and the building population as a whole, but did not provide an adequate sample size of the newer construction that comprised a relatively small portion of the overall population of buildings. Since case study homes were "randomly" encountered with no indication of a selection bias (other than age), they were included as part of the sample of homes for this study. One team also used a variation of the sampling methodology whereby only HUD Code homes (e.g., post-1976 or labeled units) were sampled. For each sampled unit, a survey form (Appendix A) was completed.

The sampling methodology resulted in a total of 105 completed survey forms suitable for statistical evaluation. Key data from the forms was coded and reviewed for quality and consistency. In addition, HUD label numbers documented during the survey were used to assign a manufacture date for each unit for which a label was present and readable. The coded data in spreadsheet format is found in Appendix B. Fortunately, the number of samples pre- and post-dating 1994 was split fairly evenly. It should be carefully noted, however, that the sampling technique employed in this survey was designed to obtain a sufficient and representative quantity of newer and older home samples. Therefore the distribution of housing ages in the sample is not reflective of the distribution of the ages of manufactured homes in the sampled population. However, the sample is considered to be representative of the population within the age categories of interest, and is therefore suitable for statistical inferences regarding differences in performance between age groups and related variations in construction characteristics. Thus the data set is valid to answer the questions posed earlier that define the main purpose of this study.

Construction Characteristics

The age distribution of the sampled manufactured homes is shown in Table 6. As mentioned, the sample age distribution does not reflect the population age distribution due to an intended sampling bias to ensure an adequate sample size representative of newer construction.

TABLE 6
Age Distribution of Sampled Manufactured Homes

Age Category	Sample Size (n)	Percent of Sample
Post-1994	52	49.5%
Pre-1994 (HUD Code only)	28	26.7%
Pre-1976 (or non-HUD Code)	17	16.2%
Undetermined Age	8	7.6%

Table Notes:

1. Post-1994 corresponds to homes manufactured after the effective date of July 13, 1994 for implementation of updated wind resistance requirements of the HUD Code.
2. Approximately 42% (22 samples) of the Post-1994 homes either post-dated the effective date of April 1, 1999 for Florida 1999 installation and foundation anchorage requirements, or otherwise met the requirements.
3. Pre-1976 indicates homes that are of unknown age, but which pre-date the initial implementation of federally-mandated standards for manufactured housing construction (i.e., HUD Code).

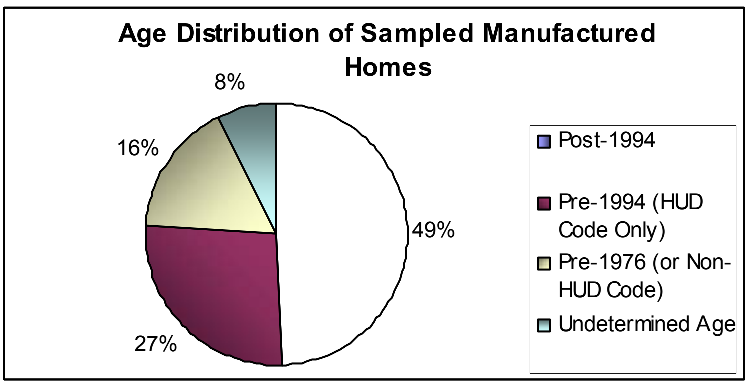


Table 7 summarizes the construction characteristics that were readily observed and documented for the different age categories of homes. Bold entries indicate the typifying characteristics for each age category. Concealed construction materials and methods are not reported due to the limited amount of destruction where such features could be readily observed. Also, the statistics of Table 7 have varying sample sizes due to the ability to collect each type of data. In particular, the sample size for wall sheathing type is relatively small due to the many occasions where siding damage was insufficient to make a non-destructive observation of the underlying sheathing type.

TABLE 7
Sampled Manufactured Housing Characteristics
By Age Category (Percent of Sample)

Characteristic	Post-1994	Pre-1994 (HUD Code only)	Pre-1976 (non-HUD Code)
No. of Units	Single – 3.8% **Multi – 96.2%**	Single – 25% **Multi – 75%**	**Single – 64.7%** Multi – 35.3%
Roofing Type	**Shingle – 96.1%** Metal – 3.9%	**Shingle – 79.2%** Metal – 20.8%	Shingle – 0 % **Metal – 100%**
Siding Type	**Vinyl – 98.0%** Metal – 2.0%	**Vinyl – 67.9%** Metal – 32.1%	Vinyl – 25% **Metal – 75%**
Wall Sheathing	**OSB – 51.6%** OSB/hdbd – 6.5% **Hardboard – 38.7%** Fiberboard – 0% Metal – 3.2% None – 0% Other – 0%	OSB – 0% OSB/hdbd – 0% Hardboard – 17.6% **Fiberboard – 29.4%** **Metal – 29.4%** None – 11.8% Other – 5.9%	OSB – 0% OSB/hdbd – 0% Hardboard – 6.7% Fiberboard – 0% **Metal – 93.3%** None – 0% Other – 0%
Foundation Anchor Spacing	**~5' – 65.4%** **6' to 8' – 26.9%** 10' or more – 7.7% None – 0%	~5' – 0% **6' to 8' – 63.6%** **10' or more – 27.3%** None – 9.1%	~5' – 0% 6' to 8' – 18.8% **10' or more – 62.5%** None – 18.8%

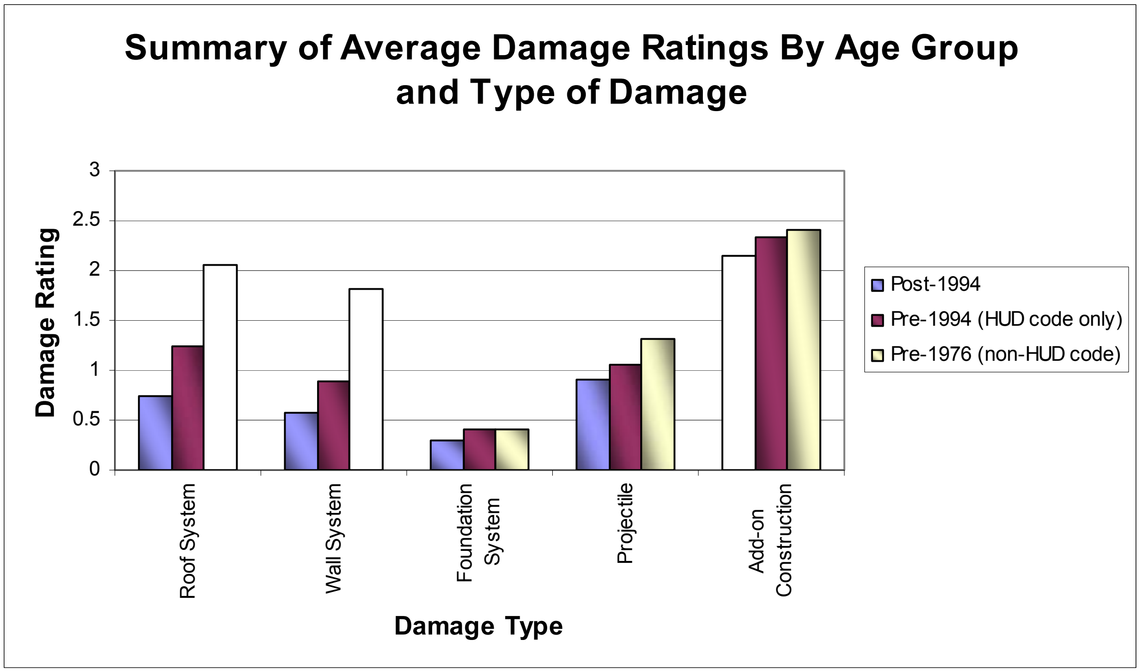
Table Notes:
1. Sample size varies within each age category and for each observed characteristic. Unknown entries in the survey forms are not included. Therefore, confidence limits on these statistics when taken as estimates of the population within various age groups may vary considerably.

Damage (Performance) Analysis

The average damage ratings for the types of damage incurred for each age group of the sampled manufactured housing stock are summarized in Table 8. 95% confidence limits are reported for each value on the bases of a two-tailed student *t* score, the sample size for each rating, and applicability of the central limit theorem. To properly interpret this data, the discrete damage rating categories (0, 1, 2, or 3) are treated as a continuous random variable such that the average damage rating must be viewed on a damage level scale of 0 to 3. Damage ratings associated with the four "points" on the damage level scale were previously described. Detailed statistics are found in Appendix C.

TABLE 8
Summary of Average Damage Ratings
By Age Group and Type of Damage
(With 95% Confidence Limits)

Damage Type	Post-1994	Pre-1994 (HUD Code only)	Pre-1976 (non-HUD Code)
Roof System	**0.75** ± 0.12	**1.25** ± 0.33	**2.06** ± 0.64
Wall System	**0.58** ± 0.14	**0.88** ± 0.29	**1.82** ± 0.64
Foundation System	**0.29** ± 0.17	**0.40** ± 0.32	**0.41** ± 0.48
Projectile	**0.91** ± 0.19	**1.05** ± 0.30	**1.31** ± 0.38
Add-on Construction	**2.14** ± 0.33	**2.33** ± 0.48	**2.41** ± 0.55



The trends in *roof and wall system performance* are clear in Table 8. Using a Separate-Variance *t* test, the differences in wall and roof system performance between the different age groups are statistically significant at a confidence level of approximately 99%. Details on the statistical inferences used to compare the average damage ratings are found in Appendix D. Thus, it can be concluded with a high level of confidence that manufactured homes built in accordance with the Post-1994 HUD Code performed significantly better than those pre-dating the revisions that were intended to improve wind performance. As mentioned, Hurricane Charley was not a design level event in most populated areas such that significant structural damage should have been observed. In agreement, the damage data reflect that the average roof and wall damage levels frequently represented by the Post-1994 construction was 0.75 and 0.58, respectively, which corresponds to the modest but frequent occurrence of exterior finish damage. In fact, none of the sampled Post-1994 homes had a damage rating greater than 1 for wall and roof systems.

Conversely, for the Pre-1994 HUD Code construction the frequencies of roof and wall system damage ratings of 2 or greater was 28.6% and 11.5%, respectively (see Appendix C). The performance of the Pre-1976 construction was notably worse, with frequencies of roof and wall system damage ratings of 2 or greater at 64.7% and 53.0%, respectively. A rating of 2 or higher corresponds to structural damage levels ranging from localized to complete destruction of the wall or roof system. Age effects, in addition to the wind load experienced, and to less stringent construction, contributed to the higher damage level of many of the older units.

In addition, the distribution of the Pre-1976 housing sample was such that a greater proportion of units were located in sites that experienced a higher wind speed. Thus, the higher observed damage level for the Pre-1976 construction was at least modestly biased by this sample distribution effect.

While the Post-1994 foundation construction methods performed well (i.e., average damage rating of 0.29 on a scale of 0 to 3 as shown in Table 8), the performance of foundations meeting the Post-99 Florida installation requirements was not flawless. For example, 9% of these foundations had a damage rating of 2 or higher, while 32 percent had a rating of 1 (refer to Table 5 for rating criteria and Appendix C for damage frequency data). For a sub-design level event, the frequency of this level of damage should have been closer to zero percent of the sampled homes.

Those units with a damage rating of 1 were generally associated with minor foundation slippage on piers and/or significant damage to skirting materials (i.e. vinyl skirting). A damage rating of 2 or higher was associated with more severe damage, such as slipping off foundation piers and toppling of single stacked masonry piers. These higher damage ratings were sometimes attributed to poor installation (i.e. improper anchor installation). Collectively, the level of observed foundation damage relative to the event magnitude indicates that the Post-99 Florida foundation requirements may not perform equivalently to a permanent foundation system as defined by HUD.

While not a statistically significant finding, the newer (Post-1994) units tended to perform better than the Pre-1994 units with regard to *projectile damage* (see Table 8 and Appendix D). Two possible explanations for this apparent trend:

(1) Newer units may have appeared to more commonly use some form of window or glazing protection (although the presence or absence of shutters was not documented in the study, since many such devices may have been removed immediately after the hurricane).
(2) Newer units also had windows tested for the higher wind pressures required by the Post-1994 Standards.

The second explanation is more likely to be a factor, because some of the observed broken glazing in older units may have been associated with a lower resistance to wind pressure. The higher wind pressure rating of windows in the newer construction probably improved the impact resistance of standard glazing by a small margin (e.g., better able to resist the impact of small debris such as roof shingle pieces, etc.) (Crandell, 2002). In addition, there are age effects to consider in the resistance of glazing to impacts and wind pressure, just as there are with other parts of a building. Impact damage ratings were also affected by the amount of damage incurred to walls, particularly siding fractures. In a relatively few cases, debris completely penetrating walls was found in the survey.

Figure 5.1: An Example of Debris Penetrating a Wall

Add-on construction was comprised of building portions that were added on to the manufactured unit after installation. These features included garages, screened porches, and carports. Typical construction of porches or carports included aluminum tube framing and thin-gauge aluminum inter-locking roofing panels. As shown in the average damage ratings of Table 8, damage to these types of add-on structures was severe and did not vary appreciably across the different age groups of construction. This type of construction was a major source of wind-borne debris, as shown in Appendix E, Figures 7.1 – 7.6. There were a few cases in the survey where the add-on construction actually performed better than the manufactured home itself (usually an older unit), but these were rare exceptions. In cases where add-ons were substantially constructed (e.g., fully sheathed with wood structural panels and anchored to a foundation or slab), the performance was observed to be good.

Figure 5.2: An Example of Substantial (Level 3) Add-On Damage

Supplemental Observations

As with any damage survey, there are important observations that depend on experience and judgment in addition to the objective sources of documentation, as presented in the previous section. This section of the report addresses such observations which were not necessarily anticipated in the design of the survey form (Appendix A) and which were not within the primary objectives of the study.

Field Installation of Siding

There were numerous instances where the siding was torn or damaged due to wind on the siding of homes, as shown in Appendix E, Figures 7.33 – 7.36. For multi-section homes (which constitute the majority of Post-1994 homes in Table 8), the siding for the end walls is installed on-site. This is done in order to ensure uniform siding on the end walls without a straight line in the center, thereby providing a better appearance.

The manufacturers are required to provide the DAPIA-approved siding installation requirements for use by installers. The field survey team noticed that a disproportionate number of the siding-related damage was on the end walls (field-installed siding). In some instances it was obvious that the fasteners used on-site were not identical to those used at the factory. The quality of the site-installed siding appears to vary. This is explainable by the fact that in factories, some workers install siding with close supervision and inspections by the manufacturer's quality control personnel as well as the In-Plant Primary Inspection Agency (IPIA). The same is not true on-site. While the installers are trained and certified in general installation techniques, they are not equally trained for proper installation of the siding.

As noted in Table 8, there was clear evidence that the roof and walls performed significantly better for the Post-1994 homes, as compared to those homes constructed prior to the effective date of the new FMHCSS with regards to wind protection. The observation team noted that in a relatively large number of cases, the wall damage was at the corners of the home. For roofs, the damage was more prominent at each end, and the overhangs showed light evidence of damage. Please note that these observations were not specifically identified as such on the survey form, but reflected the collective recollection of the team members regarding the location of damage.

There were cases where side wall damage was observed without damage to end walls. These observations may be primarily a function of wind direction. There were also cases observed where screws used for siding installation on all walls of a given unit were installed very precisely (e.g., fastened to every stud). But the fastener head size was apparently too small, allowing the vinyl siding to tear off prematurely. In addition, much of the vinyl siding damage may have been reduced by the use of wind-resistant (reinforced) nail fins. Therefore, problems with siding performance appear to include material specification issues as well as installation quality issues.

As a related topic, most homes with composition shingle roofing (the predominant roof material used on newer units) generally experienced some damage. However, major roofing damage was generally observed whenever there was add-on construction (porches, garages, etc.) attached to the main home. This damage was more severe due to the separation of add-on construction from the main home, causing roof line/siding related damage.

Roof Uplift Load Path at Ridge/Marriage Wall Joint

There were a few instances in newer and older multi-unit buildings where the roof system appeared to separate at the marriage wall joint. These instances were usually accompanied by a large window or sliding door failure that may have resulted in increased internal pressures, although probably not more than should be considered in design. The problem seemed to be related to the manner in which the over-the-roof anchor straps were terminated at the marriage of the two roofs, resulting in a discontinuous uplift load path at the ridge line. Thus, these roofs appeared to be more easily “opened up” along the ridge than if strapping had been terminated in a manner to provide a continuous load path.

Metal Anchor Strap Corrosion

In several instances, one or more metal anchor straps were found to be completely severed due to rust, even on homes not more than 10 years old, as shown in Appendix E, Figures 6.27 – 6.31. In many more cases, progressive red rust was found on anchor straps at or near to the ground level of newer homes. While this did not usually lead to any damage in Hurricane Charley, the situation will worsen as time passes. As a result of this finding, materials or coating specifications that are more resistant to degradation should be considered for strapping and installation practices. Accelerated corrosion due to the contact of galvanized strapping with moist ground or concrete should be more carefully considered in its effects on foundation longevity.

Undermining of Piers

In a number of cases, the shallow pier foundation pads were observed to be at least partially undermined by the scouring action of wind and rainwater runoff. Since these foundations are exposed once the skirting is damaged, scouring effects on shallow piers in sandy soils should be more carefully considered.

References

AF&PA, "Special Report: Hurricane Charley" (by Jeffrey Stone), *Impact*, American Forest & Paper Association, Washington, DC. September 1, 2004.

ASCE 7-02, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, VA. 2002.

ASCE 7-88, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, VA. 1993.

Crandell, J.H., *Assessment of Damage to Homes Caused by Hurricane Opal*, NAHB Research Center, Inc., Upper Marlboro, MD. January 31, 1996.

Crandell, J.H., *Assessment of Damage to Residential Buildings Caused by the Northridge Earthquake*, prepared by the NAHB Research Center, Inc. for the U.S. Department of Housing and Urban Development, Washington, DC. July 30, 1994.

Crandell, J.H., *Assessment of Damage to Single-Family Homes Caused by Hurricanes Andrew and Iniki*, prepared by NAHB Research Center, Inc. for the U.S. Department of Housing and Urban Development, Washington, DC. September 1993.

Crandell, J.H., *Housing Peformance Assessment Report: F-4 La Plata Tornado of April 28, 2002*, NAHB Research Center, Inc., Upper Marlboro, MD. June 17, 2002.

Crandell, J.H., "Statistical assessment of construction characteristics and performance of homes in Hurricanes Andrew and Opal," *Journal of Wind Engineering and Industrial Aerodynamics*, 77&78, pp695-701, 1998.

Crandell, J.H., *Wind-borne Debris Impact Resistance of Residential Glazing*, prepared by the NAHB Research Center, Inc. for the U.S. Department of Housing and Urban Development, Washington, DC. 2002.

Crandell, J.H., et al., "Near-Ground Wind and Its Characterization for Engineering Purposes," *Wind & Structures*, Vol. 3, No. 3, pp 143-158, 2000.

Crandell, J.H. and McKee, S.P., "Performance of Wood-Frame Housing in Hurricane Andrew and an Evaluation of Roof Component Reliability in Typical U.S. Wind Climates," *Wind Safety and Performance of Buildings*, Eds. Greg C. Foliente and Bo Kasal, Forest Products Society, Madison, WI. 2000.

Gurley, A., Kiesling, E., and Letchford, C., "Shielding Effects on a Manufactured Home," *Proceedings of the 11th International Conference on Wind Engineering*, Texas Tech University, Lubbock, TX. 2003.

Ho, T.C.E., *Variability of Low Building Loads*, PhD Thesis, Dept. of Civil Engineering, University of Western Ontario, London, Ontario, Canada. 1992.

HUD Code, 24 CFR, Part 3280

HUD, Permanent Foundation Guide Manufactured Housing Handbook 4930.3 1996.

McKee, S.P., and Crandell, J.H., *Evaluation of Housing Performance and Seismic Design Implications in the Northridge Earthquake*, prepared by the NAHB Research Center, Inc. for the U.S. Department of Housing and Urban Development, Washington, DC. June 1999.

NOAA, Climate of 2004 Atlantic Hurricane Season, NOAA National Climatic Data Center, August 16, 2004.
(http://www.ncdc.noaa.gov/oa/climate/research/2004/hurricanes04.html)

Powell, M. D., and S. H. Houston, 1996: Hurricane Andrew's Landfall in South Florida. Part II: Surface Wind Fields and Potential Real-time Applications. Weather. Forecast., 11, 329-349.

Powell, M. D., S. H.Houston, and T. A. Reinhold, 1996: Hurricane Andrew's Landfall in South Florida. Part I: Standardizing measurements for documentation of surface wind fields. Weather Forecast., 11, 304-328.

St. Pierre, L.M., Galsworthy, J.K., McKinnon, R., and Bartlett, F.M, "Wind Loads on Houses, A Wind Tunnel Study," ICLR Research Paper Series – No. 32, Institute for Catastrophic Loss Reduction, University of Western Ontario, Ontario, Canada. July 17, 2003.

Appendix A – Damage Survey Form

(Manufactured Homes)

Location / Development ______________________________

Name ______________________ Date ______________________

Address ______________________ ☐ Single Section

______________________ ☐ Multi Section

Orientation of Home:

Inspected by: ______________________ Interior ☐ Exterior ☐ Foundation ☐

Date of Manufacture: ______________________________

Date of Installation: ______________________________

Name of Manufacturer: ______________________________

Certification (HUD) Label: ______________________________

Serial # ______________________________

Roof Type Metal ☐ Plywood ☐ Other ______________________

Shingles ______________________________

Fasteners ______________________________

Wall

Exterior Wall Siding ______________________________

Exterior Wall Sheathing ______________________________

Windows ______________________________

Exterior Wall Framing ______________________________

Large Windows ______________________________

Sliding Doors ______________________________

Roof to Wall Connections ______________________________

Interior Wall Material

Floor Framing ______________________________

Floor Sheathing ______________________________

Wall to Floor Connections ______________________________

Size & Spacing of Steel Frame ______________________________

Outrigger Spacing ______________________________

HURRICANE JEANNE DAMAGE ASSESSMENT (CONTINUED)

Foundation

Typical Block & Piers Ground Anchors & Straps: Yes ☐ No

Anchor Spacing According to Florida Requirements

Yes ☐ No ☐

Permanent Foundation Yes ☐ No ☐ Not Sure ☐

Block Skirting Wall

Yes ☐ No ☐

Alternate Anchoring System (describe) ____________________

Conditions of Homes in Close Proximity

☐ Standing Minimal Damage

☐ Standing Significant Damage

☐ Not Standing

Describe

---

*Identify the photograph numbers for this inspection

Hurricane Jeanne Damage Assessment

Component/Location	Damage Level				Comments
	None	0-1/3	1/3-2/3	Over 2/3	
Building Condition					
Integrity of Roof					
Integrity of Walls					
Integrity of Foundation					
Projectile Damage					
Porch/Balconies					
Roof					
Roofing/Connection					
Sheathing/Connection					
Rafters/Trusses					
Soffit/Fascia					
Roof-to-Wall Connection					
Gable End Condition					
Exterior Walls					
Veneer/Siding					
Sheathing					
Wall to Floor Connections					
Windows					
Doors					
Interior Walls					
Ceilings					
Floors					
Floor Framing					
Sheathing					
Water Damage					
Foundation to Floor Connections					
Foundation					
Piers					
Straps					
Strap connections to frame					
Strap connection to anchor					
Anchor					
Type of soil					
Other					
Exposure					
Mode of Failure					
General Comments/Photograph #					

Page 3

Appendix B – Coded Survey Data

HURRICANE CHARLEY (August 13, 2004)
HUD MANUFACTURED HOUSING DAMAGE ASSESSMENT

Survey Date:	August 18 to August 21, 2004 (5 to 8 days after event)	
Survey Extent:	17 manufactured housing developments, from Pine Island inland to Northeast of Port Charlotte	
Total Number of Units Surveyed:	**110**	(includes samples from selected developments and case studies of post-94 units when encountered)

TEAMS:

1	Rick, Ashok, Roger*
2	Lane, Shawn, Jay*
3	Lane, Roger*
4	Shawn, Jay*
	* = recorder

Damage Rating Key
(typical rating criteria):

ROOF	0=no damage, 1=exterior finish damage only, 2=sheathing/gable damage, 3=partial or full roof blow-off
WALL	0=no damage, 1=exterior finish damage only, 2=sheathing/local damage but standing, 3=partial or full wall collapse
FOUNDATION	0=no damage, 1=minor shifting apparent, 2=significant shifting but on piers and standing and/or few piers collapsed, 3=roll-over or shifted off piers
PROJECTILE	0=no damage, 1=few wall impacts and/or limited glass breakage, 2=large impact and/or 1/3 or more windows broken, 3=many impacts and/or most glass broken
ADD-ONS	0=no damage, 1=roofing damage, but standing, 2=partial collapse, 3= total collapse
OVERALL	-- uses worst rating for roof, wall, or foundation (does not include projectile or add-on ratings)

Notes on Survey Sheets 1-62 only:

NOTE: #55-62 case studies in Port Charlotte Village were surrounded by older (pre-94) units with 13 of 64 (about 20 percent) having severe roof or roof and wall damage (up to total destruction)
No post-94 units were found with severe damage in survey samples or case studies.

General Conclusions:

1. No permanent foundation installations found in sample or case studies.
2. Post-94 units performed better than Pre-94 units on average for roof, wall, and foundation performance.
3. Negligible difference in performance relative to projectile and add-on performance for all age groups.
4. Add-on (e.g., aluminum carport or porch posts and roofing) performance was notably bad, except in few cases where add-on garages were built to meet wind code (e.g., plywood or OSB sheathing, strapping, anchors into concrete footings, etc.)
5. Wind data is forthcoming. Wind event was likely less than 145 sustained (standard meterological conditions) for study area. Estimated wind speed was probably in the range of 90 to 110 mph (sustained) for the study region based on 10m elevation and open exposure. This estimate is based on experience with tree, infrastructure, and building damage for other recent events (e.g., Andrew and Opal) which bracket the level of damage observed.
6. Suburban and sheilded (treed) exposures played a significant role in reducing wind loads experienced relative to HUD Code basis for design. Even so, there were notable differences in post- and pre-94 unit performance. The wind loads were not sufficient to determine performance at loading levels exceeding or approaching intended safety margins for design (e.g., overturning safety margin of 1.5 was not "tested").
7. Rusted through uplift and shear strapping was found on several buildings, including many no more than 7 to 10 years old.
8. Age effects (as well as difference in construction requirements) may explain some of the difference between Pre- and Post-94 unit performance.
9. Better performance of overall Post-94 group vs. subset of Post-99 units needs further study to explain and additional samples.

10. Not all samples are included in this preliminary analysis.

Summary Damage Rating Statistics (Sheets 1-62 only):

Average (all)	1.2	1.0	0.3	1.2	2.3	**1.4**
Average (pre-94)	1.6	1.4	0.3	1.2	2.3	**1.8**
Average (post-94)	1.0	0.5	0.1	1.1	2.3	**1.0**
Average (post-99)	0.8	0.9	0.6	1.3	2.4	**1.1**
	ROOF	WALL	FND	PROJ.	ADD-ON	OVERALL

Sample size varies; Post-99 sample is relatively small.
Age of units is not confirmed in many cases.

SURVEY LOGISTICS				UNIT CHARACTERISTICS				
Sheet No.	Site No.	Devel Name	Street Address	No. of Sections	Age Category	HUD Code?	Date of Manuf.	HUD Label No.
1	1	Lakeland Village	#100, 5601 D	2	pre-94	Yes	1/28/1992	FLA 492270
2	1	Lakeland Village	#97	2	pre-94	Yes	8/27/1992	FLA 503818,
3	1	Lakeland Village	#94	2	pre-94	Yes	1/6/1994	FLA 538398
4	1	Lakeland Village	#105	2	post-94	Yes	4/3/1997	FLA 614436
5	1	Lakeland Village	#108	2	post-94	Yes	7/13/1995	FLA 572515
6	1	Lakeland Village	#111	2	post-94	Yes	9/10/1996	FLA 601661
7	2	Pine Acres	? Bernaden R	1	pre-94	Unk	Unk	Unk
8	2	Pine Acres	6539 Bernade	1	pre-94	No	Unk	none
9	2	Pine Acres	? Bernaden R	1	pre-94	No	Unk	none
10	2	Pine Acres	6585 Bernade	1	pre-94	No	Unk	none
11	2	Pine Acres	6736 Bernade	2	pre-94	Yes	Unk	Yes (unreada
12	2	Pine Acres	1801 Polly Ct	1	pre-94	No	Unk	none
13	2	Pine Acres	1812 Holly Ct	2	post-94	Yes	3/13/1995	FLA 563068
14	3	Ventura Lakes	69 Foxfire Ct.	2	post-94	Yes	6/6/2003	FLA 740525,
15	3	Ventura Lakes	71 Foxfire Ct.	2	post-94	Yes	10/31/2001	FLA 715731
16	3	Ventura Lakes	73 Foxfire Ct.	2	post-94	Yes	Unk	Unk
17	3	Ventura Lakes	75 Foxfire	2	post-94	Yes	Unk	Unk
18	4	Riverside Oaks	84 Heatherwo	2	post-94	Yes	2/10/1998	FLA 636582
19	4	Riverside Oaks	87 Heatherwo	2	post-94	Yes	6/17/1997	FLA 620890
20	4	Riverside Oaks	90 Heatherwo	2	post-94	Yes	1/23/1997	FLA 610027
21	4	Riverside Oaks	93 Heatherwo	2	post-94	Yes	Unk	Unk
22	5	September Estates	Ferrell Rd.	1	post-94	Yes	11/24/1997	FLA 032467
23	5	September Estates	Ferrell Rd.	1	pre-94	No	Unk	none
24	5	September Estates	Ferrell Rd.	1	pre-94	Yes	7/30/1979	FLA 088901
25	12	Windmill	2 Den Helder	2	pre-94	No	Unk	none
26	12	Windmill	6 Den Helder	2	post-94	Yes	4/7/1995	FLA 566202
27	12	Windmill	8 Den Helder	1	pre-94	No	Unk	none
28	12	Windmill	7 Rotterdam	2	post-99	Yes	6/19/2001	FLA 709650
29	12	Windmill	6 Rotterdam	2	pre-94	Unk	Unk	sn: CH12714
30	12	Windmill	14 Den Helde	2	pre-94	No	Unk	none
31	12	Windmill	21 Den Helde	2	pre-94	No	Unk	none
32	13	Buttonwood Village	187 Buttonwo	1	post-99	Yes	11/25/2003	FLA 747514
33	13	Buttonwood Village	184 Buttonwo	2	post-94	Yes	12/14/1995	FLA 583230,
34	13	Buttonwood Village	181 Buttonwo	1	pre-94	No	Unk	none
35	13	Buttonwood Village	178 Buttonwo	1	pre-94	No	Unk	none
36	13	Buttonwood Village	126? Buttonw	2	post-99	Yes	6/10/2004	FLA 756628
37	13	Buttonwood Village	127 Buttonwo	2	post-99	Yes	6/10/2004	FLA 756626
38	13	Buttonwood Village	175 Buttonwo	1	pre-94	Yes	1/19/1978	FLA 039492
39	13	Buttonwood Village	172 Buttonwo	1	pre-94	Yes	doesn't exist	FLA 894865
40	13	Buttonwood Village	171 Buttonwo	2	post-99	Yes	8/1/2004	FLA 759807,
41	9	Burnt Store Colony	22 Colony Pk	2	pre-94	Yes	8/13/1990	FLA 462950
42	9	Burnt Store Colony	32 Colony Pk	2	pre-94	Yes	2/7/1986	FLA 317262
43	9	Burnt Store Colony	41 Colony Pk	2	pre-94	Yes	1/12/1990	FLA 447995
44	14	S. Punta Gorda	795 Almar Dr	2	pre-94	Unk	Unk	unk
45	14	S. Punta Gorda	4100 Almar	1	pre-94	No	Unk	none
46	14	S. Punta Gorda	4130 Almar D	2	post-99	Yes	12/16/2002	FLA 733879
47	14	S. Punta Gorda	4132 Almar	2	pre-94	No	Unk	none
48	14	S. Punta Gorda	4300 Almar	1	pre-94	No	Unk	none
49	14	S. Punta Gorda	4330 Almar	1	pre-94	No	Unk	none

SURVEY LOGISTICS				UNIT CHARACTERISTICS				
Sheet No.	Site No.	Devel Name	Street Address	No. of Sections	Age Category	HUD Code?	Date of Manuf.	HUD Label No.
50	14	S. Punta Gorda	4420 Almar	2	pre-94	No	Unk	none
51	14	S. Punta Gorda	4520 Almar	2	pre-94	No	Unk	none
52	14	S. Punta Gorda	4610 Almar	2	pre-94	Unk	Unk	Unk
53	14	S. Punta Gorda	5022 Almar	2	post-99	Yes	4/2/2004	FLA 753611
54	14	S. Punta Gorda	5100 Almar	2	post-99	Yes	2/19/2002	FLA 720907
55	16	Port Charlotte Villa	241 Weatherl	2	post-99	Yes	10/12/1999	FLA 680638,
56	16	Port Charlotte Villa	66 Weatherby	2	post-99	Yes	2/26/2001	FLA 704723
57	16	Port Charlotte Villa	220 Club Ln	2	post-99	Yes	2/7/2002	FLA 720878
58	16	Port Charlotte Villa	191 Club Ln	2	post-99	Yes	7/28/2000	FLA 693715
59	16	Port Charlotte Villa	#335	2	post-94	Yes	6/25/1997	FLA 619713,
60	16	Port Charlotte Villa	#49	2	post-94	Yes	11/15/1997	FLA 631771
61	16	Port Charlotte Villa	#32	2	post-94	Yes	8/22/1997	FLA 622779
62	17	Harbor View Park	#12E	2	post-99	Yes	11/5/1999	FLA 681234,
63	1	Lakeland Village	#113 ?	2	Unk	Unk	Unk	Unk
64	1	Lakeland Village	#107 ?	2	post-94	Yes	9/16/1994	FLA 553562
65	1	Lakeland Village	#203	2	post-94	Yes	6/24/1998	FLA 647827
66	1	Lakeland Village	#220	2	post-94	Yes	8/16/1996	FLA 597891
67	1	Lakeland Village	#121	2	post-94	Yes	1/31/1996	FLA 585473,
68	1	Lakeland Village	#207	2	Unk	Unk	Unk	Unk
69	1	Lakeland Village	#104	2	post-94	Yes	10/22/1997	FLA 629843,
70	1	Lakeland Village	#117	2	post-94	Yes	10/28/1997	FLA 628401
71	2	Pine Acres	#3A, 6526	2	pre-94	Yes	12/4/1980	FLA 139970,
72	2	Pine Acres	6672	1	pre-94	Yes	5/17/1989	FLA 427152
73	2	Pine Acres	6559	1	pre-94	Yes	4/26/1983	FLA 213576
74	2	Pine Acres	6626	1	pre-94	Yes	1/20/1989	FLA 414633
75	2	Pine Acres	6525	1	pre-94	Yes	4/8/1983	FLA 213401
76	3	Ventura Lakes	#94	2	post-99	Yes	6/12/2003	FLA 740352
77	4	Riverside Oaks	#98, Sandlew	2	post-94	Yes	2/3/1995	FLA 564260
78	4	Riverside Oaks	#101	2	pre-94	Yes	2/14/1992	FLA 493939
79	4	Riverside Oaks	#102	2	post-94	Yes	10/13/1995	FLA 579554
80	4	Riverside Oaks	#17	2	pre-94	Yes	1/12/1993	FLA 512743
81	5	September Estates	15246 Buzzar	2	post-99	Yes	1/23/2001	FLA 702674
83	5	September Estates	15300 Buzzar	2	pre-94	Yes	10/12/1984	GEO 311160
84	5	September Estates	Farrell St.	2	post-99	Yes	6/14/2004	FLA 757891
85	8	Cherry Estate	3057 Sloop L	2	post-99	Yes	2/11/2002	FLA 720134
86	8	Cherry Estate	3025 Sloop L	2	post-99	Yes	7/21/2003	FLA 742089
87	8	Cherry Estate	2991 Sloop L	2	post-99	Yes	7/20/2001	FLA 710889
88	8	Cherry Estates	2970 Sloop L	2	post-99	Yes	1/11/2002	FLA 718007
89	12	Windmill	3 Amsterdam	2	pre-94	Unk	Unk	Unk
90	12	Windmill	14 Alligator	2	post-94	Yes	7/16/1996	FLA 647885
91	13	Buttonwood Village	64 Clarendow	2	pre-94	Yes	6/17/1988	FLA 394848
92	13	Buttonwood Village	69 Clarendon	2	pre-94	Yes	2/13/1992	FLA 493558
93	13	Buttonwood Village	73 Buttonwoo	2	post-99	Yes	7/22/2003	FLA 742362
94	13	Buttonwood Village	72 Buttonwoo	2	pre-94	Yes	2/25/1994	FLA 541485
97	9	Burnt Store Colony	#172, 15550 I	2	pre-94	Yes	1/29/1988	FLA 384809
98	9	Burnt Store Colony	#37	2	post-99	Yes	5/3/2004	FLA 755241
99	9	Burnt Store Colony	#38	2	pre-94	Yes	3/15/1988	FLA 387675
101	12	Windmill	#19 Amsterda	2	pre-94	Unk	Unk	Unk
103	3	Ventura Lakes	#91	2	post-99	Yes	9/28/2001	FLA 713969
104	14	By the Sea	5341 River Ba	2	post-94	Yes	1/18/1999	FLA 661379,
105	14	By the Sea	5535 River Ba	2	pre-94	Yes	1/1/1989	Unk
106	14	By the Sea	5511 River Ba	2	pre-94	Yes	8/13/1993	FLA 528884,
107	14	By the Sea	5471 River Ba	2	pre-94	Yes	1/1/1990	Unk
108	14	By the Sea	5465 River Ba	2	post-99	Yes	6/21/2004	FLA 757345,
109	14	By the Sea	5447 River Ba	2	pre-94	Yes	1/1/1990	Unk
110	14	By the Sea	5415 River Ba	2	pre-94	Yes	1/1/1986	Unk

Total Number of Samples = 105

Unk = "unknown" and means either form was left blank or data was not obtainable for various reasons.

CONSTRUCTION & SITE CHARACTERISTICS							
Sheet No.	Roofing Type	Siding Type	Bracing Type	Fnd Anc present?	Anchor Spacing (ft)	Meet 99 req's?	Wind Exposure
1	Shingle	Vinyl	Fiberboard	Yes	Unk	No	B
2	Shingle	Vinyl	Fiberboard	Unk	Unk	Unk	B
3	Shingle	Vinyl	Fiberboard	Yes	Unk	Unk	B
4	Shingle	Vinyl	Hardboard	Unk	Unk	Unk	B
5	Shingle	Vinyl	OSB	Unk	Unk	Unk	B
6	Shingle	Vinyl	OSB	Yes	Unk	Unk	B
7	Metal	Metal	Unk	Yes	8	No	B-tree
8	Metal	Metal	Metal	No	None	No	B-tree
9	Metal	Metal	Metal	Yes	10	No	B-tree
10	Metal	Alum	Unk	No	None	No	B-tree
11	Shingle	Alum	Unk	Yes	10	No	B
12	Metal	Metal	Metal	No	Unk	No	B
13	Shingle	Vinyl	OSB/hdbrd	Yes	5	Yes	B
14	Shingle	Vinyl	Hardboard	Unk	Unk	Unk	B
15	Shingle	Vinyl	Hardboard	Unk	Unk	Unk	B
16	Shingle	Vinyl	Hardboard	Unk	Unk	Unk	B
17	Shingle	Vinyl	Hardboard	Unk	Unk	Unk	B
18	Shingle	Vinyl	Unk	Yes	8	No	B-tree
19	Shingle	Vinyl	Unk	Yes	8	No	B-tree
20	Shingle	Vinyl	Unk	Yes	8	No	B-tree
21	Shingle	Vinyl	Unk	Yes	10	No	B-tree
22	Metal	Metal	Metal	Yes	20	No	B-tree
23	Metal	Metal	Metal	Yes	12	No	B-tree
24	Metal	Vinyl	Metal	Yes	10	No	B-tree
25	Metal	Metal	Metal	Yes	6	No	B
26	Shingle	Vinyl	OSB	Yes	5	Yes	B
27	Metal	Metal	Metal	Yes	10	No	B-shielded
28	Metal	Vinyl	OSB	Yes	5	Yes	B
29	Metal	Vinyl	Hardboard	Yes	10	No	B
30	Metal	Metal	Hardboard	Yes	20	No	B
31	Metal	Metal	Metal	Yes	14	No	B
32	Shingle	Vinyl	Unk	Yes	5	Yes	B
33	Shingle	Vinyl	OSB/hdbrd	Yes	5	Yes	B
34	Unk	Unk	Unk	Yes	8	No	B
35	Metal	Metal	Metal	Yes	8	No	B
36	Shingle	Vinyl	Unk	Yes	5	Yes	B
37	Shingle	Vinyl	Unk	Yes	5	Yes	B
38	Metal	Metal	Metal	Yes	10	No	B
39	Metal	Metal	Metal	Yes	8	No	B
40	Shingle	Vinyl	Hardboard	Yes	5	Yes	B
41	Shingle	Vinyl	Unk	Yes	6	No	B
42	Shingle	Alum	Unk	Yes	8	No	B
43	Metal	Vinyl	Unk	Yes	8	No	B
44	Metal	Vinyl	Unk	Yes	10	No	B
45	Metal	Vinyl	Metal	Yes	10	No	B
46	Shingle	Vinyl	Hardboard	Yes	5	Yes	B
47	Metal	Metal	Metal	Yes	12	No	B
48	Metal	Vinyl	Metal	Unk	Unk	No	B
49	Metal	Metal	Metal	Yes	12	No	B

CONSTRUCTION & SITE CHARACTERISTICS							
Sheet No.	Roofing Type	Siding Type	Bracing Type	Fnd Anc present?	Anchor Spacing (ft)	Meet 99 req's?	Wind Exposure
50	Metal	Vinyl	Metal	Yes	12	No	B
51	Metal	Vinyl	Metal	Yes	16	No	B
52	Metal	Vinyl	Metal	Unk	Unk	No	B
53	Shingle	Vinyl	OSB	Yes	5	Yes	B
54	Shingle	Vinyl	OSB	Yes	5	Yes	B
55	Shingle	Vinyl	OSB	Yes	5	Yes	B
56	Shingle	Vinyl	OSB	Yes	5	Yes	B
57	Shingle	Vinyl	OSB	Yes	5	Yes	B
58	Shingle	Vinyl	OSB	Yes	5	Yes	B
59	Shingle	Vinyl	OSB	Yes	6	No	B
60	Shingle	Vinyl	OSB	Yes	8	No	B
61	Shingle	Vinyl	OSB	Yes	7	No	B
62	Shingle	Vinyl	Hardboard	Yes	5	Yes	B
63	Shingle	Vinyl	none	Yes	Unk	Unk	B
64	Shingle	Vinyl	Unk	Yes	Unk	Unk	B
65	Shingle	Vinyl	Unk	Yes	Unk	No	B
66	Shingle	Unk	Unk	Yes	Unk	No	B
67	Shingle	Vinyl	Hardboard	Yes	Unk	No	B
68	Shingle	Unk	Unk	Yes	Unk	Unk	B
69	Shingle	Vinyl	Hardboard	Unk	Unk	Unk	B
70	Shingle	Vinyl	OSB	Yes	Unk	Unk	B
71	Unk	Metal	None	Yes	Unk	No	B
72	Shingle	Metal	Unk	Yes	Unk	Unk	B
73	Shingle	Metal	Metal	Yes	Unk	Unk	B
74	Shingle	Metal	Metal	Yes	8	No	B
75	Metal	Metal	Unk	Yes	Unk	Unk	B
76	Shingle	Vinyl	Unk	Unk	Unk	Unk	B
77	Shingle	Vinyl	Unk	Yes	Unk	Unk	B-tree
78	Shingle	Vinyl	Un k	Yes	Unk	Unk	B-tree
79	Shingle	Vinyl	Hardboard	Yes	Unk	Unk	B-tree
80	Shingle	Vinyl	Fiberboard	Yes	Unk	Unk	B-tree
81	Shingle	Vinyl	Unk	Yes	Unk	Yes	B-tree
83	Shingle	Vinyl	Hardboard	No	None	No	B-tree
84	Shingle	Vinyl	Unk	Yes	Unk	Yes	B-tree
85	Shingle	Vinyl	OSB	Unk	Unk	Unk	B-tree
86	Shingle	Vinyl	Unk	Unk	Unk	Unk	B-tree
87	Shingle	Vinyl	Unk	Yes	Unk	Unk	B-tree
88	Shingle	Vinyl	Unk	Unk	Unk	Unk	B-tree
89	Metal	Metal	Unk	Yes	Unk	No	B
90	Shingle	Vinyl	Unk	Yes	Unk	Unk	B
91	Shingle	Vinyl	none	Yes	Unk	No	B
92	Shingle	Vinyl	Foamboard	Yes	Unk	No	B
93	Shingle	Unk	Unk	Unk	Unk	Unk	B
94	Unk	Vinyl	Unk	Unk	Unk	Unk	B
97	Shingle	Vinyl	Unk	Unk	Unk	No	B
98	Shingle	Vinyl	Unk	Unk	Unk	Yes	B
99	Shingle	Vinyl	Unk	Yes	Unk	No	B
101	Metal	Vinyl	Metal	Yes	Unk	Unk	B
103	Shingle	Vinyl	Hardboard	Yes	Unk	Unk	B
104	Unk	Vinyl	OSB	Yes	6	No	B
105	Unk	Vinyl	Masonite	Unk	Unk	No	B
106	Shingle	Vinyl	Fiberboard	Unk	Unk	No	B
107	Shingle	Vinyl	Unk	Yes	8	No	B
108	Shingle	Vinyl	Unk	Yes	5	Yes	B
109	Shingle	Vinyl	Hardboard	Yes	Unk	No	B
110	Unk	Vinyl	Hardboard	Yes	8	No	B

DAMAGE RATINGS						
Sheet No.	Roof	Walls	Foundation	Projectile	Add-ons	Overall
1	2	1	0	2	3	2
2	2	1	0	2	3	2
3	1	0	0	2	3	1
4	1	0	0	1	1	1
5	1	0	0	1	1	1
6	1	0	0	1	3	1
7	0	1	0	0	0	1
8	0	0	0	1	0	0
9	3	3	2	1	3	3
10	0	0	0	0	0	0
11	1	0	0	1	2	1
12	3	3	2	Unk	3	3
13	1	1	2	2	n/a	2
14	1	1	0	1	3	1
15	1	1	0	1	1	1
16	1	0	0	1	3	1
17	1	0	0	0	3	1
18	0	0	0	0	2	0
19	0	0	0	0	1	0
20	1	0	0	0	2	1
21	1	0	0	1	0	1
22	1	1	0	2	3	1
23	1	0	3	1	3	3
24	1	1	0	Unk	3	1
25	3	3	0	2	3	3
26	1	1	0	2	3	1
27	1	1	0	2	2	1
28	1	1	0	2	2	1
29	1	2	1	3	3	2
30	1	1	0	1	3	1
31	3	2	0	1	2	3
32	0	0	0	1	3	0
33	1	1	0	1	3	1
34	3	3	0	Unk	3	3
35	3	1	0	1	3	3
36	1	1	1	1	n/a	1
37	1	1	3	1	n/a	3
38	0	1	0	1	3	1
39	1	2	1	1	3	2
40	1	1	1	1	n/a	1
41	0	0	0	1	1	0
42	1	1	0	0	1	1
43	0	0	0	0	0	0
44	3	1	0	2	3	3
45	3	3	0	2	3	3
46	1	1	1	1	3	1
47	3	3	0	Unk	3	3
48	2	1	0	2	3	2
49	3	3	0	Unk	3	3

DAMAGE RATINGS						
Sheet No.	Roof	Walls	Foundation	Projectile	Add-ons	Overall
50	0	1	0	1	3	1
51	3	3	0	2	1	3
52	1	1	0	1	3	1
53	0	1	0	1	0	1
54	1	1	1	2	n/a	1
55	1	1	0	2	2	1
56	1	1	1	1	3	1
57	1	1	0	2	3	1
58	1	1	0	1	3	1
59	1	1	0	1	3	1
60	1	1	0	1	3	1
61	0	1	0	1	2	1
62	1	1	0	1	3	1
63	1	1	0	1	n/a	1
64	1	1	1	Unk	3	1
65	1	1	1	1	2	1
66	1	1	1	1	3	1
67	1	1	0	Unk	3	1
68	1	1	0	Unk	3	1
69	1	0	0	Unk	2	1
70	1	0	0	1	3	1
71	3	3	1	2	n/a	3
72	1	0	0	0	3	1
73	1	1	Unk	Unk	3	1
74	2	2	2	Unk	Unk	2
75	2	1	1	1	2	2
76	0	0	0	0	0	0
77	1	0	0	1	2	1
78	1	1	Unk	Unk	Unk	1
79	1	1	0	1	3	1
80	3	1	Unk	Unk	3	3
81	1	0	0	0	3	1
83	1	1	Unk	Unk	Unk	1
84	0	0	0	1	Unk	0
85	1	1	Unk	Unk	Unk	1
86	0	0	0	0	0	0
87	0	0	0	0	2	0
88	0	0	0	0	0	0
89	3	2	Unk	2	Unk	3
90	1	0	1	0	2	1
91	2	1	Unk	Unk	Unk	2
92	1	1	2	1	Unk	2
93	1	1	0	0	2	1
94	1	1	Unk	1	3	1
97	1	Unk	Unk	1	Unk	1
98	0	0	1	Unk	0	1
99	1	1	0	1	3	1
101	1	1	1	1	Unk	1
103	1	1	0	Unk	3	1
104	0	1	0	1	Unk	1
105	3	1	0	1	3	3
106	0	0	0	1	1	0
107	1	0	0	0	0	1
108	0	0	0	1	n/a	0
109	1	Unk	Unk	2	3	1
110	1	1	1	1	3	1

Appendix C - Detailed Construction Characteristic and Damage Data

SUMMARY OF DAMAGE RATINGS FOR ENTIRE SAMPLE

ENTIRE SAMPLE (HUD and non-HUD homes of all ages) (n= 105)						
Rating Statistics	Roof	Walls	Foundation	Projectile	Add-ons	Overall
AVG RATING=	**1.14**	**0.91**	**0.34**	**1.05**	**2.26**	**1.26**
Std Error =	**0.09**	**0.08**	**0.07**	**0.07**	**0.12**	**0.09**
95% Conf. Limits =	**0.17**	**0.16**	**0.14**	**0.15**	**0.23**	**0.18**
Std DEV =	0.90	0.84	0.68	0.68	1.08	0.90
COV =	0.79	0.92	2.01	0.65	0.48	0.71
n =	105	103	95	87	86	95
Damage Frequencies	Roof	Walls	Foundation	Projectile	Add-ons	Overall
% with 0 rating	20.0%	31.1%	75.8%	19.5%	12.8%	14.7%
% with 1 rating	60.0%	55.3%	16.8%	57.5%	9.3%	60.0%
% with 2 rating	5.7%	4.9%	5.3%	21.8%	17.4%	9.5%
% with 3 rating	14.3%	8.7%	2.1%	1.1%	60.5%	15.8%
TOTALS	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Unknown entries not included)

(NOTE: averaging of the entire data set is somewhat meaningless since the sampling method did not follow actual age distribution of population of manufactured housing units. However, it does characterize the overall sample. It is not representative of overall manufactured housing population performance. Within age groups below, the damage statistics are representative.)

Note:
All confidence limits are based on Student t with 0.05 level of significance. Std Error = Std DEV / sqrt (n) and is the standard error estimate for the mean or average damage rating.

Reference:
Ott, Lyman, An Introduction to Statistical Methods and Data Analysis, Third Edition, PWS-Kent Publishing Company, Boston, MA. 1988.

SAMPLE DISTRIBUTION BY MAP STUDY SITE NUMBERS

Map Site No. =	1	2	3	4	5	8	9	12	13	14	16	17	TOTAL
Samples (n) =	14	12	6	8	6	4	6	10	13	18	7	1	105

SUMMARY OF DAMAGE RATINGS BY AGE CATEGORIES

1994 - PRESENT HUD-CODE HOMES (n= 52)						
Rating Statistics	Roof	Walls	Foundation	Projectile	Add-ons	Overall
AVG RATING=	**0.75**	**0.58**	**0.29**	**0.91**	**2.14**	**0.88**
Std Error =	**0.06**	**0.07**	**0.09**	**0.09**	**0.16**	**0.07**
95% Conf. Limits =	**0.12**	**0.14**	**0.17**	**0.19**	**0.33**	**0.15**
Std DEV =	0.44	0.50	0.61	0.63	1.08	0.52
COV =	0.58	0.86	2.07	0.69	0.51	0.58
n =	52	52	51	46	43	51
Damage Frequencies	Roof	Walls	Foundation	Projectile	Add-ons	Overall
% with 0 rating	25.0%	42.3%	76.5%	23.9%	14.0%	17.6%
% with 1 rating	75.0%	57.7%	19.6%	60.9%	9.3%	78.4%
% with 2 rating	0.0%	0.0%	2.0%	15.2%	25.6%	2.0%
% with 3 rating	0.0%	0.0%	2.0%	0.0%	51.2%	2.0%
TOTALS	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Unknown entries not included)

SUB-SAMPLE DISTRIBUTION BY MAP STUDY SITE NUMBERS

Map Site No. =	1	2	3	4	5	8	9	12	13	14	16	17	TOTAL
Samples (n) =	9	1	6	6	3	4	1	3	6	5	7	1	52

CONSTRUCTION CHARACTERISTICS (% of sampled homes, unknowns not included)

No. of	1 unit	2 or more	Siding	Vinyl	Metal	Alum				
Units	3.8%	96.2%	Type	98.0%	2.0%	0.0%				
Roofing	Shingle	Metal	Wall Shtg	OSB	SB/hardboa	Hardboard	Fiberboard	Metal	Foamboard	None
Type	96.1%	3.9%	Type	51.6%	6.5%	38.7%	0.0%	3.2%	0.0%	0.0%
Foundation		5' or less	6' to 8'	10' or more	None					
Anchor Spacing		65.4%	26.9%	7.7%	0.0%					

PRE-1994 HUD CODE UNITS ONLY (n= 28)						
Rating Statistics	Roof	Walls	Foundation	Projectile	Add-ons	Overall
AVG RATING=	**1.25**	**0.88**	**0.40**	**1.05**	**2.33**	**1.35**
Std Error =	**0.16**	**0.14**	**0.15**	**0.15**	**0.23**	**0.20**
95% Conf. Limits =	**0.33**	**0.29**	**0.32**	**0.30**	**0.48**	**0.41**
Std DEV =	0.84	0.71	0.68	0.67	1.06	0.88
COV =	0.68	0.80	1.70	0.64	0.46	0.65
n =	28	26	20	21	21	20
Damage Frequencies	Roof	Walls	Foundation	Projectile	Add-ons	Overall
% with 0 rating	14.3%	26.9%	70.0%	19.0%	9.5%	15.0%
% with 1 rating	57.1%	61.5%	20.0%	57.1%	14.3%	45.0%
% with 2 rating	17.9%	7.7%	10.0%	23.8%	9.5%	30.0%
% with 3 rating	10.7%	3.8%	0.0%	0.0%	66.7%	10.0%
TOTALS	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Unknown entries not included)

SUB-SAMPLE DISTRIBUTION BY MAP STUDY SITE NUMBERS

Map Site No. =	1	2	3	4	5	8	9	12	13	14	16	17	TOTAL
Samples (n) =	3	6	0	2	2	0	5	0	5	5	0	0	28

CONSTRUCTION CHARACTERISTICS (% of sampled homes, unknowns not included)

No. of	1 unit	2 or more	Siding	Vinyl	Metal	Alum					
Units	25.0%	75.0%	Type	67.9%	25.0%	7.1%					
Roofing	Shingle	Metal	Wall Shtg	OSB	SB/hardboa	Hardboard	Fiberboard	Metal	Foamboard	None	Other
Type	79.2%	20.8%	Type	0.0%	0.0%	17.6%	29.4%	29.4%	5.9%	11.8%	5.9%
Foundation		5' or less	6' to 8'	10' or more	None						
Anchor Spacing		0.0%	63.6%	27.3%	9.1%						

Appendix C (continued)

PRE-1976 (NON-HUD CODE UNITS ONLY) (n= 17)						
Rating Statistics	Roof	Walls	Foundation	Projectile	Add-ons	Overall
AVG RATING=	**2.06**	**1.82**	**0.41**	**1.31**	**2.41**	**2.24**
Std Error =	**0.30**	**0.30**	**0.23**	**0.17**	**0.26**	**0.28**
95% Conf. Limits =	**0.64**	**0.64**	**0.48**	**0.38**	**0.55**	**0.59**
Std DEV =	1.25	1.24	0.94	0.63	1.06	1.15
COV =	0.61	0.68	2.28	0.48	0.44	0.51
n =	17	17	17	13	17	17
Damage Frequencies	Roof	Walls	Foundation	Projectile	Add-ons	Overall
% with 0 rating	17.6%	17.6%	82.4%	7.7%	11.8%	11.8%
% with 1 rating	17.6%	29.4%	0.0%	53.8%	5.9%	17.6%
% with 2 rating	5.9%	5.9%	11.8%	38.5%	11.8%	5.9%
% with 3 rating	58.8%	47.1%	5.9%	0.0%	70.6%	64.7%
TOTALS	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Unknown and n/a entries not included)

SUB-SAMPLE DISTRIBUTION BY MAP STUDY SITE NUMBERS

Map Site No. =	1	2	3	4	5	8	9	12	13	14	16	17	TOTAL
Samples (n) =	0	4	0	0	1	0	0	4	2	6	0	0	17

CONSTRUCTION CHARACTERISTICS (% of sampled homes, unknowns not included)

No. of	1 unit	2 or more	Siding	Vinyl	Metal	Alum					
Units	64.7%	35.3%	Type	25.0%	68.8%	6.3%					
Roofing	Shingle	Metal	Wall Shtg	OSB	SB/hardboa	Hardboard	Fiberboard	Metal	Foamboard	None	Other
Type	0.0%	100.0%	Type	0.0%	0.0%	6.7%	0.0%	93.3%	0.0%	0.0%	0.0%
Foundation		5' or less	6' to 8'	10' or more	None						
Anchor Spacing		0.0%	18.8%	62.5%	18.8%						

SUMMARY OF DAMAGE RATINGS BY FOUNDATION ANCHORAGE METHOD

POST-1994 HUD CODE UNITS MEETING FLORIDA 1999 FOUNDATION ANCHORAGE REQUIREMENTS (n= 22)						
Rating Statistics	Roof	Walls	Foundation	Projectile	Add-ons	Overall
AVG RATING=	**0.77**	**0.77**	**0.55**	**1.29**	**2.40**	**1.00**
Std Error =	**0.09**	**0.09**	**0.17**	**0.12**	**0.27**	**0.13**
95% Conf. Limits =	**0.19**	**0.19**	**0.35**	**0.26**	**0.58**	**0.27**
Std DEV =	0.43	0.43	0.80	0.56	1.06	0.62
COV =	0.56	0.56	1.47	0.44	0.44	0.62
n =	22	22	22	21	15	22
Damage Frequencies	Roof	Walls	Foundation	Projectile	Add-ons	Overall
% with 0 rating	22.7%	22.7%	59.1%	4.8%	13.3%	13.6%
% with 1 rating	77.3%	77.3%	31.8%	61.9%	0.0%	77.3%
% with 2 rating	0.0%	0.0%	4.5%	33.3%	20.0%	4.5%
% with 3 rating	0.0%	0.0%	4.5%	0.0%	66.7%	4.5%
TOTALS	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Unknown and n/a entries not included)

Appendix D - Statistical Inferences

STATISTICAL TESTS OF DIFFERENCES IN MEAN DAMAGE RATINGS

(Separate-Variance t Test)

Level of significance is the minimum level at which the null hypothesis (e.g., average performance is not different) can be rejected in favor of the research hypothesis that group 1 performance is better (e.g., lower average damage rating) than group 2. Confidence level is inverse of level of significance and is the maximum value at which the null hypothesis (i.e., no difference) may be rejected.

A. (1) Post 1994 vs. (2) Pre-1994 HUD code units only

	Roof	Walls	Foundation	Projectile	Add-ons	Overall
avg1-avg2=	-0.5000	-0.3077	-0.1059	-0.1346	-0.1938	-0.4676
s1 =	0.4372	0.4989	0.6097	0.6263	1.0819	0.5156
n1 =	52	52	51	46	43	51
s2 =	0.8444	0.7114	0.6806	0.6690	1.0646	0.8751
n2 =	28	26	20	21	21	20
t' =	-2.929068	-1.975743	-0.606804	-0.779016	-0.68014	-2.242122
c =	0.126168	0.197331	0.239413	0.285751	0.335286	0.11984
DOF =	34	37	31	36	40	24
Significance	0.003016	0.027839	0.2742	0.220531	0.250167	0.017231
Confidence	99.6984%	97.2161%	72.5800%	77.9469%	74.9833%	98.2769%

B. (1) Post-1994 vs. (2) Pre-1976 non-HUD code units

	Roof	Walls	Foundation	Projectile	Add-ons	Overall
avg1-avg2=	-1.3088	-1.2466	-0.1176	-0.3946	-0.2722	-1.3529
s1 =	0.4372	0.4989	0.6097	0.6263	1.0819	0.5156
n1 =	52	52	51	46	43	51
s2 =	1.2485	1.2367	0.9393	0.6304	1.0641	1.1472
n2 =	17	17	17	13	17	17
t' =	-4.238095	-4.049829	-0.483557	-1.995835	-0.888715	-4.706472
c =	0.038549	0.050511	0.123149	0.2181	0.290117	0.063089
DOF =	17	17	20	19	29	18
Significance	0.000277	0.000416	0.316976	0.030245	0.190734	8.8E-05
Confidence	99.9723%	99.9584%	68.3024%	96.9755%	80.9266%	99.9912%

C. (1) Pre-1994 HUD Code vs. (2) Pre-1976 non-HUD code units

	Roof	Walls	Foundation	Projectile	Add-ons	Overall
avg1-avg2=	-0.8088	-0.9389	-0.0118	-0.2601	-0.0784	-0.8853
s1 =	0.8444	0.7114	0.6806	0.6690	1.0646	0.8751
n1 =	28	26	20	21	21	20
s2 =	1.2485	1.2367	0.9393	0.6304	1.0641	1.1472
n2 =	17	17	17	13	17	17
t' =	-2.363018	-2.838259	-0.042941	-1.141736	-0.225869	-2.60255
c =	0.217338	0.177894	0.308521	0.410799	0.447582	0.330904
DOF =	24	22	28	26	34	29
Significance	0.013285	0.004783	0.483027	0.131985	0.411328	0.007214
Confidence	98.6715%	99.5217%	51.6973%	86.8015%	58.8672%	99.2786%

Appendix E - Photographs

Figure 6.1: Destroyed Add-On Construction

Figure 6.2: Destroyed Add-On Construction

Figure 6.3: Destroyed Add-On Construction

Figure 6.4: Destroyed Add-On Construction


Figure 6.5: Destroyed Add-On Construction


Figure 6.6: Destroyed Add-On Construction

Figure 6.7: Damaged Sidewall and Endwall Siding


Figure 6.8: Destroyed Manufactured Home Built Prior to 1976

Figure 6.9: Destroyed Manufactured Home

Figure 6.10: Destroyed Manufactured Home

Figure 6.11: Failure of Wall and Roof System

Figure 6.12: Destroyed Manufactured Home

Figure 6.13: Destroyed Manufactured Home Built Prior to 1976

Figure 6.14: Destroyed Manufactured Home Built Prior to 1976

Figure 6.15: Destroyed Manufactured Home Built Prior to 1976

Figure 6.16: Destroyed Manufactured Home

Figure 6.17: Failure of Roof System

Figure 6.18: Manufactured Home Survived the Hurricane Wind Forces

Figure 6.19: Manufactured Home Survived the Hurricane Wind Forces


Figure 6.20: Manufactured Home Survived the Hurricane Wind Forces

Figure 6.21: Manufactured Home with Shutters Survived Hurricane Wind Forces

Figure 6.22: Manufactured Home Slightly Shifted from its Foundation

Figure 6.23: Manufactured Home Slightly Shifted from its Foundation

Figure 6.24: Manufactured Home Installed in Accordance with Florida Installation Law with Anchors at about 5 ft. on Center.

Figure 6.25: Manufactured Home Installed with Short Ground Anchors

Figure 6.26: Manufactured Home Installed with Alternative Anchoring System


Figure 6.27: Corroded Ground Anchor Strap


Figure 6.28: Corroded Ground Anchor Strap

Figure 6.29: Corroded Ground Anchor Strap

Figure 6.30: Corroded Ground Anchor Strap

Figure 6.31: Corroded Ground Anchor Strap

Figure 6.32: Damaged Corner Part of the Home

Figure 6.33: Damaged Endwall Siding

Figure 6.34: Damaged Endwall Siding

Figure 6.35: Damaged Endwall Siding

Figure 6.36: Damaged Endwall Siding

Figure 6.37: Scouring Action of Wind and Rain Water Runoff

Figure 6.38: Scouring Action of Wind and Rain Water Runoff