

Hurricane Survivability for Manufactured Housing: A Case Study in Disaster Mitigation for Low-Income Housing

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Abstract

An unprecedented hurricane season during 2004 saw four major hurricanes impact Florida within a span of six weeks. These storms left more than 3,000 people dead, including 152 in the U.S. The 2004 hurricane season also caused over \$US 42B in damage. Of 152 manufactured home communities and 29,274 manufactured homes surveyed in Florida, 3,583 (12.24%) units were totally destroyed or non-reparable. 44,640 (40%) of the state's 113,620 dwelling units receiving government assistance for structural damage were manufactured housing units. However, manufactured housing units constructed after the 1994 U.S. Manufactured Housing Construction and Safety Standard survived intact with little or no damage. This paper provides manufactured housing damage assessment data from 60 of 67 Florida counties affected by the 2004 Hurricane season, an analysis of common failure modes in pre-1994 housing stock, and new research on methods and materials incorporated by manufacturers following the 1994 HUD code amendment. It is anticipated that the research herein may assist the international community in providing safe and sustainable housing for rapidly developing countries experiencing population growth.

Keywords

Manufacturing, Wind-load Engineering, Affordable Housing, Hurricanes, Codes and Standards

1. Introduction

Florida, along with California and Texas, lead the nation in low-income populations, and ironically, in the number of manufactured housing units. In 2003, Florida ranked second only to Texas in the number of manufactured homes sold and placed at 10,900 units (U.S. Census, 2003). Tragically, an unprecedented hurricane season in 2004 saw four major hurricanes with sustained winds ranging from 105-145mph at landfall, impact 60 of 67 counties in Florida within a span of six weeks (DHSMV, 2004). These storms left more than 3,000 people dead, including 152 in the U.S., making 2004 the deadliest hurricane season since 1969 when a category 5 hurricane named Camille devastated coastal Louisiana. The 2004 hurricanes also caused over \$US 42B in damage, more than any other hurricane season or natural disaster in U.S. history (Explores!, 2005). Among the destruction were more than 3,600 manufactured housing units in 152 mobile home communities surveyed by the Florida Department of Highway Safety and Motor Vehicles (DHSMV). Capturing the headlines and airwaves were images of complete destruction of many mobile home parks throughout Florida (Figure 1). Comparatively little attention however was given to manufactured housing units produced after 1994, when the U.S. Department of Housing and Urban

Development (HUD) enacted wind-load amendments to the former 1976 HUD Code. In fact, preliminary reports by state and federal officials found that these units, and units installed to the Florida's 1999 tie-down requirements, suffered little or no damage as older units nearby sustained damage ranging from severe to catastrophic (Figure 2).

This paper provides manufactured housing damage assessment data from 60 of 67 Florida counties affected by the 2004 Hurricane season according to unit manufacture date, occupancy demographics and observed modes of failure. For comparative purposes, damage assessments will be categorized according to the following:

- Units produced before 1994.
- Units produced after 1994 when wind load amendments to the 1976 Federal Manufactured Home Construction Safety Standards were adopted following Hurricane Andrew in 1992.
- Units produced and installed after 1999 when Florida enacted Rule Chapter 15C-1 Florida Administrative Code (FAC), requiring the nation's most stringent tie-down standards.



Figure 1: Hurricane damage to pre-1994 HUD manufactured housing (FMHA, 2004)



Figure 2: Comparison of hurricane damage to pre-1994 HUD and post-1994 HUD manufactured housing (FMHA, 2004)

2. 2004 Hurricanes

On Friday, August 13, 2004, Hurricane Charley came ashore from the Gulf at Charlotte Harbor with 145mph sustained winds on a fast 22mph northeast track through the state. The eye of the hurricane traversed the harbor and heavily damaged homes in Punta Gorda and Port Charlotte before heading across central Florida and exiting the state near Daytona Beach. Late Saturday, September 5, 2004, Hurricane Frances made landfall near Stuart from the Atlantic with winds of 105mph moving slowly at 5mph to the west-northwest. The eye of this hurricane was so large the National Hurricane Center reported the eye wall to encompass three coastal counties. In the early morning hours of September 16, 2004, Hurricane Ivan came ashore west of Pensacola, exposing much of the Florida panhandle to hurricane force winds. As powerful as Charley and as large as Frances, the onshore, counterclockwise rotation produced storm surge exceeding 15 feet (DHSMV, 2004).

Table 1: Category 3 or greater hurricanes impacting Florida in 2004, (InfoPlease, 2005)

Hurricane	Dates	Maximum Winds	Deaths	U.S. Damage (\$Millions)
Charley	9-14 Aug	150	15	14,000
Frances	25 Aug – 8 Sep	145	7	8,860
Ivan	2-24 Sep	165	95	13,000
Jeanne	13-29 Sep	120	3000+	6,500
Totals				42,360

Following a nearly identical track as Frances three weeks prior, Hurricane Jeanne became the fourth major hurricane to score a direct hit on Florida within a span of 6 weeks. From north of Miami to south of Jacksonville, this 400-mile wide storm with sustained winds exceeding 120mph destroyed hundreds of manufactured housing units damaged or weakened by Frances three weeks earlier (DHSMV, 2004).

3. Federal Manufactured Housing Construction and Safety Standards Act

In 1974, Congress required the Secretary of U.S. Housing and Urban Development (HUD) to establish minimum requirements for manufactured housing construction and safety, effective June 15, 1976. In response to the devastation caused by Hurricane Andrew in 1992, HUD amended its regulations governing mobile home construction under Title 24 Code of Federal Regulations (CFR) in 1994 (DHSMV, 2004). With the destruction of 97% of all manufactured homes in the path of Hurricane Andrew, compared to 11% of site built homes, the 1994 HUD amendments created a “Wind Zone III” category for 14 coastal counties of Florida, requiring manufactured housing placed in these areas to withstand 110mph wind loads (Jordan, 2004). HUD Wind Zone II (100-mph) remained in effect throughout the rest of Florida since no area of the state is greater than 65 miles from the coast. The 1994 amendments required manufactured housing to be designed by a professional engineer or registered architect to withstand the wind loads and airborne debris impact requirements of each wind zone. As a result, common engineered changes in manufactured housing located in Wind Zone III included:

- Minimum connections between floor, wall and roof assemblies (26ga. galvanized straps 16” o.c.)
- Larger floor joists (2”x8” and 2”x10” nominal) and sub-floor sheathing (5/8” and 3/4”)
- Larger side-wall and end-wall studs (2”x4” and 2”x6” nominal), closer spacing (16”o.c.)
- Improved attachment of exterior coverings and sheathing (6 fasteners per shingle)
- Increased resistance and protection of windows to wind loads and airborne debris
- Increased number of shear walls (4-6 per unit)
- Increased wall and roof sheathing thickness (3/8”-1/2” OSB)
- Trusses doubled within 3’-0” of each end (16” o.c.)

In addition, HUD has specified “Exposure D” areas for manufactured units in Wind Zone III within 1,500 feet of the coastline. Homes constructed for these areas require additional strengthening.



Figure 3: Improved sub-floor sheathing ($\frac{3}{4}$ " laminated and fastened to 2x10 floor joists (Draper, 2005)



Figure 4: Roof trusses reduced from 24" o.c. to 16" o.c. and doubled at end walls. Drywall laminated to truss bottom chords (Draper, 2005)

4. Rule Chapter 15C Florida Administrative Code

In addition to the 1994 HUD amendments, the DHSMV implemented a mobile home installer program in 1996, requiring the testing, licensing and sanctioning of individuals who install mobile homes in accordance with Rule Chapters 15C-1 and 15C-2 of the Florida Administrative Code (FAC). These administrative rules provide standards for mobile home foundations, anchors and anchoring straps used to secure the unit to the ground. These rules were revised in 1999 in response to damage caused by F2 tornadoes in central Florida killing 39 people in mobile homes during the early morning hours of March 9, 1998. Key changes to these administrative rules in 1999 include:

- Galvanized anchors and straps
- Sidewall and frame ties 5'-4" o.c.
- Longitudinal anchors, 2 per I-beam per end
- Center line ties within 2'-0" of each end
- Anchor soil testing

In addition, the Florida Department of Community Affairs (DCA) has implemented a Mobile Home Tie-Down Enhancement program to bring older manufactured housing units up to 1999 tie-down standards.



Figure 5: Improved end and marriage wall stud dimensions (2x4 and 2x6) and maximum spacing (Draper, 2005)



Figure 6: Increased number of tie-downs and maximum spacing (Draper, 2005)

5. Research Findings

Teams from DHSMV conducted damage assessments in 152 communities impacted by one or more 2004 hurricanes. Of the 29,274 manufactured homes surveyed, 3,583 (12.24%) pre-1994 HUD units were totally destroyed or non-reparable. Qualifying for this designation, units must sustain roof or exterior wall damage so severe that the cost to repair the unit and interior water damage would be prohibitive. In contrast, none of 4,056 post-1994 HUD units surveyed were destroyed or seriously damaged (Table 2).

Table 2: Hurricane survivability of pre-1994 HUD and post-1994 HUD manufactured housing (DHSMV, 2004)

Hurricane	Number of Manufactured Homes	Pre-1994 HUD	Destroyed	Post-1994 HUD	Destroyed or Seriously Damaged
Charley	11,909	9,011	2,413 (26.8%)	2,898	0 (0.0%)
Frances	7,089	6,961	99 (1.4%)	128	0 (0.0%)
Ivan	1,432	1,246	82 (6.6%)	186	0 (0.0%)
Jeanne	8,845	8,001	989 (12.4%)	844	0 (0.0%)
Totals	29,275	25,219	3,583 (14.2%)	4,056	0 (0.0%)

Homes built prior to the 1976 HUD Code did not perform well. Damages were attributed to inadequate anchors, corroded anchors, or penetrations of the exterior walls and windows of the units by wind-borne debris. Car ports, screened rooms and other add-ons attached to units failed and removed portions of walls and roof assemblies, exposing units to rapid pressurization and progressive fatigue and failure. In thirty-three communities surveyed immediately following Hurricane Charley for example, approximately 75% of carports, awnings, sheds and additions collapsed or became airborne debris hazards for adjacent structures. Roof-overs and one-piece membrane roof covers performed poorly, having too few fasteners and too little bight (length). This allowed a large percentage to be blown off, leading to progressive structural failure or unsalvageable water damage. FEMA flood zone requirements for elevating the foundation I-beam above the base flood elevation resulted in catastrophic uplift. Concrete foundations (pads), patios and walkways placed in contact with tie-downs corroded straps. Moisture entrained by concrete and poor undercarriage ventilation (1sf per 150sf of floor area) led to premature rotting and termite damage of floor joists, wall plates and other structural components (Jordan, 2004)

Damage experienced by manufactured units built after 1976 but prior to the 1994 amendments were similarly related to envelope exposures from the destruction of carports, screened rooms and awnings and impact damage from such add-on structures not covered by the HUD Code. A relatively smaller number of these units were observed to have shifted off their foundations when compared to pre-1976 HUD Code units (DHSMV, 2004). Post-1994 HUD units performed well, experiencing in all observed cases comparatively minor and repairable damage resulting from add-on failures and airborne debris damage. Unlike pre-1994 HUD Code units, post-1994 units did not experience progressive failure following the loss of an add-on structure. Damage was limited to the immediate and affected area of the attachment. Unlike the retirement communities of south Florida however, panhandle areas impacted by Ivan consisted largely of working families, more tree canopy and fewer carports, awnings and additions. As a result, manufactured housing in these areas sustained comparatively less wind damage (DHSMV, 2004).

Homes installed or retrofitted in accordance with Rule Chapter 15C-1 (FAC), remained on their foundations with no movement as a result wind loads or floodwater, with the exception of three homes impacted by storm surge from Hurricane Ivan. However, many retrofitted pre-1994 HUD units were nevertheless destroyed by other causes unrelated to foundation stability (DHSMV, 2004). A study of Florida households sustaining structural damage from the 2004 Hurricanes using data compiled from FEMA disaster assistance registration shows that 3,890 (66%) of 5,901 dwelling units destroyed were manufactured homes (Table 3). In addition, 44,640 (40%) of the state's 113,620 dwelling units receiving FEMA assistance for structural damaged were manufactured housing units. Of these, 37,399 (84%) had annual household incomes of \$30,000 or less. In all, approximately 7.65% of the state's nearly 600,000 manufactured housing units

sustained damage from one or more of the 2004 hurricanes compared to 1.8% of the single-family dwelling stock and 0.54% of multifamily units (Stroh and Smith, 2004)

Table 3: Level of damage vs. household income for occupants living in manufactured housing (Stroh and Smith, 2004)

Level of Damage	≤ \$30,000	\$30,001-\$40,000	\$40,001-\$50,000	\$50,001-\$60,000	\$60,000+	Total
Destroyed	3,126	389	189	87	99	3,890
Major	9,347	1,029	426	187	183	11,172
Moderate	8,914	919	366	169	157	10,525
Minor	16,012	1,620	772	336	313	19,053
Total	37,399	3,957	1,753	779	752	44,640

Of 113,620 total single-family households sustaining structural damage in Florida, 74,458 “heads of household” were 61 years of age or less. A third as many, or some 24,240 heads of household were 62 years of age or older. Of these, 86.7% had annual incomes of \$US 30,000 or less. Although unknown at this time, it is expected that the majority of this elderly, low-income population owned manufactured homes sustaining minor to catastrophic hurricane damage. No age information was available on 14,922 households sustaining structural damage (Stroh and Smith, 2004).

6. Conclusions

Findings from the Manufactured Housing Institute (MHI) concluded that overall, performance of homes built to the post-1994 HUD Code was very good. Homes built to the 1976 HUD Code failed at an alarming rate. Federal codes enacted in 1976 and amended in 1994 were observed to have a profound effect on the vulnerability of manufactured housing units to hurricanes, as were Florida’s 1996 installer license and 1999 Rule 15C tie-down requirements. However, add-on structures not covered under the 1994 HUD Code or Florida Rule 15C will continue to pose a significant hazard to manufactured housing.

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