Performance of Manufactured Housing in Louisiana during Hurricanes Katrina and Rita

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ABSTRACT

The August and September 2005 landfalls of Hurricanes Katrina and Rita caused heavy property damage in coastal Louisiana. Following the landfall of these hurricanes a systematic survey assessing the performance of manufactured housing in the areas that were affected by winds from these hurricanes was undertaken. Goals were to assess the wind damage resisting performance of newer manufactured homes, as well as older manufactured housing and site built homes for comparison. A research team was sent to perform damage documentation surveys during October of 2005. The research team for each day of field work consisted of 2 to 3 researchers from the LSU Hurricane Center and an inspector from the Louisiana Manufactured Housing Commission. Surveys were conducted in areas affected by Hurricane Rita located in or near Vinton, Toomey, Sulphur, Hackberry and Lake Charles, Louisiana. The surveys of areas affected by Hurricane Katrina were conducted in or near Belle Chasse, Port Fourchon and Grand Isle, Louisiana.

Results indicate that manufactured housing built and installed after implementation of the 1994 HUD rule on wind standards performed well structurally and in regard to anchorage. Wind speeds in the study area did not reach design speeds for the post-1994 HUD wind zone rated units in either storm and few units that were poorly anchored or lacking any anchorage suffered significant damage related to anchorage failure. The frame structure of the newer units was not visibly damaged in any case. Cladding damage was more common on the post-1994 units than in any of the other age groups. This is due to the building practices used in the newer units, the walls and roof are first sheathed, usually with plywood or OSB then covered with vinyl siding for walls and asphalt shingles on the roof, while older models typically used sheet metal siding and roofing. Vinyl siding and roof shingles on the post 1994 HUD rule manufactured units had a higher occurrence of loss when compared to the loss of metal siding and roofing on the older housing.

INTRODUCTION

Prior to 1974 there was no significant regulation of manufactured housing. The National Manufactured Housing Construction and Safety Standards Act of 1974 was implemented with the stated purpose of reducing the number of deaths and the amount of property damage resulting from manufactured home accidents, and to improve the quality and durability of manufactured homes. It also conferred authority to the Secretary of HUD to issue, amend, or revoke any Federal manufactured home construction or safety standard. Following hurricane Andrew in 1992 the department undertook investigations of damage to manufactured housing that led to a proposed rule change. The Manufactured Home Construction and Safety Standards on Wind Standards Rule became effective in July 1994 with some regulations implemented by January

1995 [1]. The purpose of the rule is to increase the safety of manufactured homes, thereby reducing deaths and injuries and extensive property damage losses in areas where wind-induced damage is a particular hazard and risk. Improved resistance of manufactured homes to wind forces in areas prone to hurricanes was to be accomplished by raising design wind speeds in coastal zones prone to hurricanes. Zone II homes are to be design for a basic wind speed of 100 mph while Zone III has a basic design wind speed of 110 mph. The HUD rule references ASCE7-88 [2] for wind loads based on the prescribed design wind speeds. ASCE7-88 uses a fastest mile wind speed as the basic wind speed for wind load calculations. A table is provided with the HUD Rule detailing wind pressures for particular elements of manufactured housing per wind zone. It also has notes that exempt shingles and exterior wall coverings from evaluation for the design wind pressures if prescribed fastening schedules are used. The rule prompted design and construction changes leading to improved anchorage systems, more robust Main Wind Force Resisting Systems, and the use of structural sheathing clad with vinyl siding and asphalt shingles.

METEOROLOGICAL DATA

Meteorological data on hurricanes Katrina and Rita were gathered from the National Climatic Data Center, a part of the National Oceanic and Atmospheric Administration [3]. Hurricane Katrina made an initial landfall in south Florida on August 25th, 2005. That landfall occurred between Hallandale Beach and North Miami Beach, Florida, with wind speeds of approximately 80 mph. Katrina then strengthened to a category 5 storm as it moved West and North toward the North Central Gulf Coast. Although tropical cyclones of category 5 strength are rarely sustained for long durations, Katrina remained a major hurricane despite weakening due to the entrainment of dryer air and an opening of the eye wall to the south and southwest and again made landfall in the early morning of August 29th near Grand Isle, Louisiana. It was a very large storm and impacted a broad area of the Gulf coast.

Following less than a month after Hurricane Katrina devastated large parts of southeast Louisiana and Mississippi and Alabama, Hurricane Rita devastated southwest Louisiana and southeast Texas. While in the Gulf of Mexico, Rita had peak sustained winds of 175 mph. Weakening occurred during the 36 hours prior to landfall but Rita brought hurricane strength winds more than 150 miles inland and caused significant damage. Hurricane Rita made landfall along the Texas/Louisiana border early on September 24th.

Wind field graphics were obtained from the Atlantic Oceanographic and Meteorological Laboratory (AOML) [4]. AOML is one of the Oceanic and Atmospheric Research Facilities of the National Oceanic and Atmospheric Administration (NOAA). NOAA/AOML is a part of the US Department of Commerce located in Miami, Florida. Figure 1 displays the NOAA Hurricane Research Division estimated wind fields for the survey areas affected by Hurricane Katrina. The image has superimposed markers for the towns in which the surveyed communities are located. Isotachs over land surface represent the maximum estimated one-minute sustained wind speeds, at 33 ft above ground, for flat, open terrain. Grand Isle is estimated to have experienced sustained winds between 80 and 85 mph, while Port Fourchon and Belle Chasse both experienced sustained wind speeds likely between 75 and 80 mph. Fastest mile wind speeds at these three locations can be determined from the estimated sustained winds, and are 77, 82, and 88 mph respective to the 75, 80 and 85 mph estimated sustained winds. The three-second peak gust estimated from the NOAA data in the vicinity of Belle Chasse is between 92 and 98 mph. This compares well with a peak gust of 101 mph measured by a research meteorological tower deployed at the New Orleans Naval Air Station Joint Reserve Base in Belle Chasse, by the Florida Coastal Monitoring Program, one of the few reliable meteorological measurements in southeast Louisiana during the storm. The Belle Chasse FCMP tower deployment was located less than 2 miles from the Country Corner survey site and less than 4 miles from the Forest Dr. survey site.

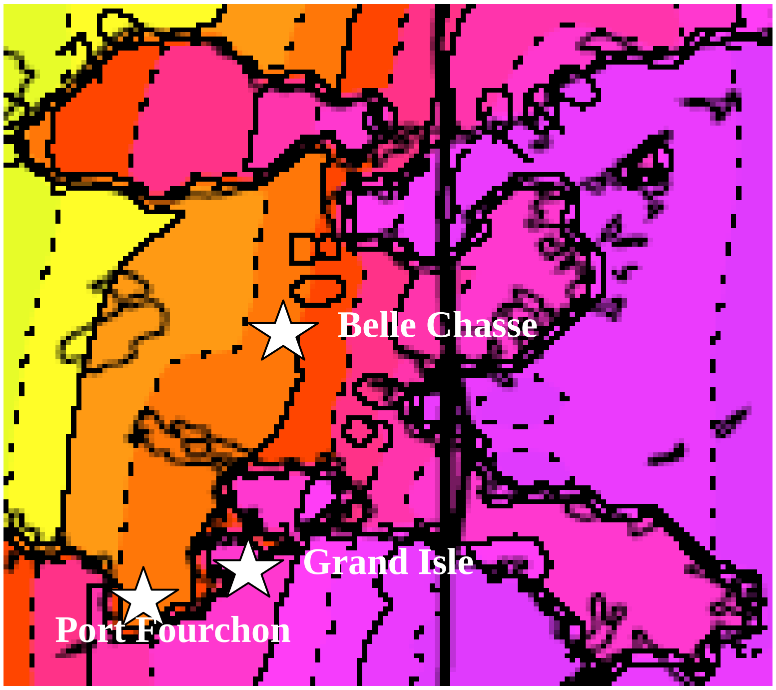

Figure 1: Wind field for Hurricane Katrina

Figure 2 is the wind field for the areas affected by Hurricane Rita. Toomey, Vinton and Hackberry are estimated to have experienced sustained winds between 70 and 75 mph.

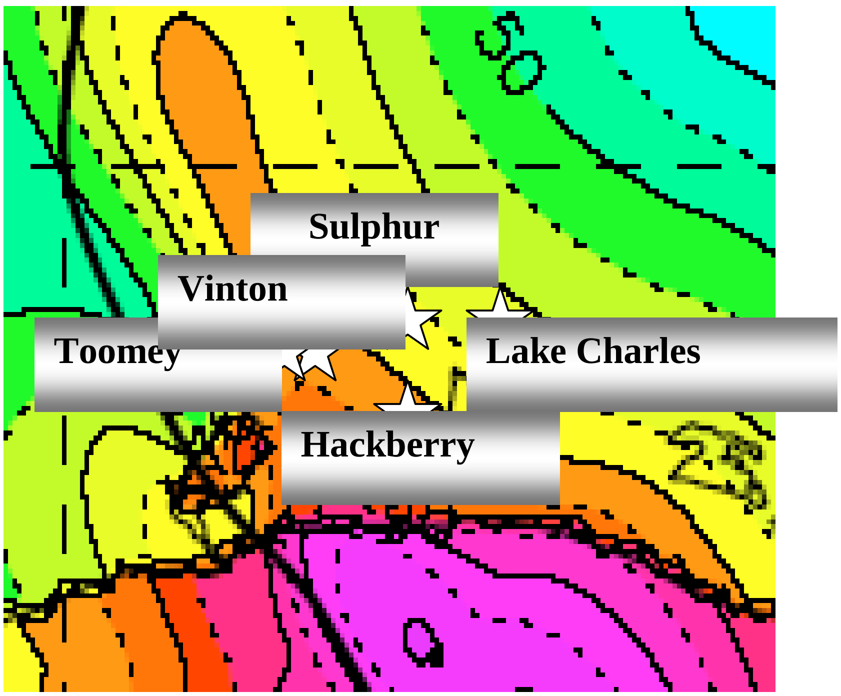

Figure 2: Wind field for Hurricane Rita

Near Sulphur the estimated sustained winds were between 65 and 70 mph, while Lake Charles had estimated sustained winds between 60 and 65 mph. Fastest mile wind speeds at these three locations were determined from the estimated sustained winds, and are 60, 66, 72 and 77 mph respective to the 60, 65, 70 and 75 mph estimated sustained winds. The three-second peak gust estimated from the NOAA data are 73, 79, 85 and 92 mph corresponding to the 60, 65, 70 and 75 mph estimated sustained winds. Local terrain also affects the wind speed at heights that are relevant for single story housing. All wind speeds presented are estimates for flat, open terrain (e.g., airports, excluding buildings). Wooded and built up suburban areas will have locally lower wind speeds than flat open areas.

None of the communities surveyed appear to have experienced wind speeds equal to or greater than the design wind speeds required by the 1994 HUD standards. The HUD standards require a design wind speed of 100 mph for Zone II and 110 mph for Zone III. The HUD basic design wind speeds are fastest mile wind speeds. Figures 3 & 4 are the US and Louisiana HUD Basic wind zone maps for manufactured housing design wind speeds.

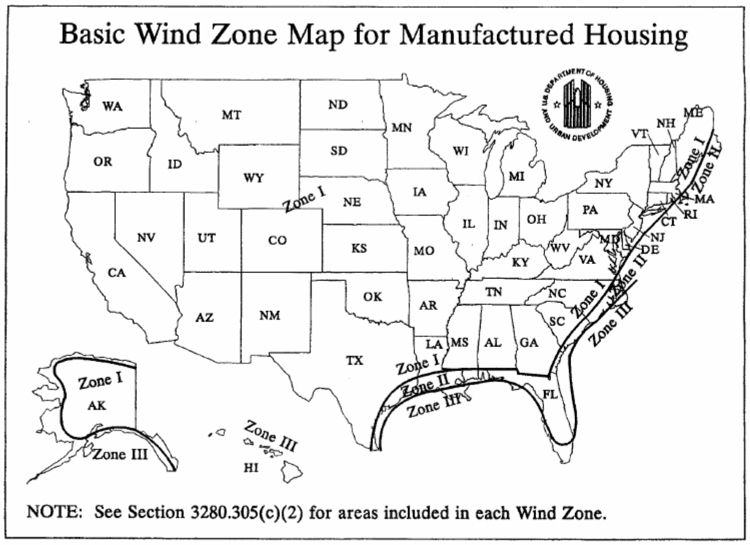

Figure 3: HUD Basic Wind Zone Map for Manufactured Housing

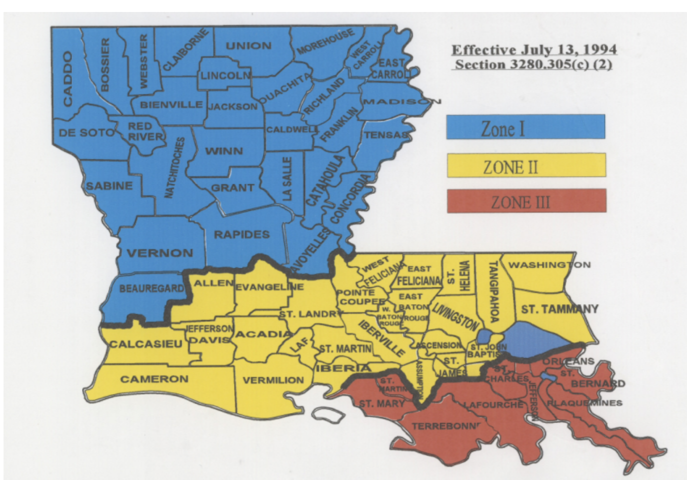

Figure 4: Louisiana HUD Basic Wind Zone Map for Manufactured Housing

CHARACTERISTICS OF COMMUNITIES SURVEYED

Twelve manufactured housing communities were surveyed. Surveys were done with two different levels of detail. Ten had detailed documentation and two were cursory surveys for lightly damaged communities. A visit to Grand Isle did not lead to a survey due to flood and wave damage along with wind damage to most of the manufactured housing viewed. However, photographs and material for general commentary on overall performance of newer manufactured housing versus older units were obtained in Grand Isle.

Some communities were occupied entirely by manufactured housing units, others were combined manufactured housing and site built homes. Some of the areas surveyed had relatively new manufactured housing while others had just older units or a mix of older and newer units. The wind exposure also varied relative to location, with some parks in relatively open areas, some in suburban or heavily wooded areas; one park was protected by a tree line in an otherwise open area. Table 1 displays the location, storm that affected the area, wind speed in 1-minute sustained average and fastest mile, surrounding terrain, tree intensity in close proximity to housing, ASCE 7 Exposure category, HUD wind zone and community housing makeup.

Table 1: Information about surveyed communities

Community	Location	Storm	Windspeed 1-minute avg. (AMOL)	Windspeed Fastest Mile (HUD)	HUD Wind Zone	Surrounding Terrain	Trees	Exp. Cat.	Community Housing Makeup				
			(mph)	(mph)					Total MH	Pre-74	74-94	Post-94	Site Built
Forrest Dr.	Belle Chasse, LA	Katrina	75-80	77-82	3	Open	Few	C	49	6	18	25	4
Charley Hardison's	Port Fourchon, LA	Katrina	75-80	77-82	3	Open	None	C	4		1	3	
C-Port	Port Fourchon, LA	Katrina	75-80	77-82	3	Open	None	C	10			10	
Country Corner	Belle Chasse, LA	Katrina	75-80	77-82	3	Suburban	None	B	34		11	23	
Glen Meadow	Vinton, LA	Rita	70-75	72-77	2	Tree Line	Tree Line	C	26	10	12	4	
Twin Oaks	Sulphur, LA	Rita	65-70	66-72	2	Open	Few	C	58			58	
Savoy Rd.	Sulphur, LA	Rita	65-70	66-72	2	Wooded	Heavy	B	10	8	1	1	7
Autumn Acres	Toomey, LA	Rita	70-75	72-77	2	Wooded	Heavy	B	21	15	6		
Stewart Rd.	Toomey, LA	Rita	70-75	72-77	2	Open	Very Few	C	21	16	5		
Devall Rd.	Hackberry, LA	Rita	70-75	72-77	2	Open	Very Few	C	18	5	10	3	8
Patton St., Sulphur	Sulphur, LA	Rita	65-70	66-72	2	Wooded	Few	B	80		31	49	
C Wait, Lake Charles	Lake Charles, LA	Rita	60-65	60-66	2	Open	None	C	52		2	50	

SURVEYS

Data collected included size, date of manufacture, HUD zone rating for post-1994 units, height of blocking, number of anchors, and the damage assessment. A photograph was also taken of each unit in the complete surveys. Most areas visited had very few residents home at the time of inspection. HUD data labels and wind zone information are typically posted only inside of the newer units, making the expertise of the LMHC member critical to the team. When residents were home access to the label was typically granted and the information was taken from the label. Additional information was also collected whenever possible. That information includes HUD label number, serial number, manufacturer, an assessment of anchorage adequacy/code compliance, condition of the anchorage, and type of anchors. When not able to determine it directly, the age was estimated by the team member from the Louisiana Mobile Home

Commission based on characteristics of pre-1974, 1974-1994, and post-1994 manufactured housing. The LMHC team member also estimated the HUD wind zone rating of the post-1994 units when that data was not directly available.

The quick surveys were made in two relatively newer communities where damage was minimal, consisting primarily of vinyl siding and shingle loss and no pre-1974 units present. The survey was made by assessing the damage level of a unit and adding that unit to a count of either pre-1994 or post-1994 units divided by damage class. These counts also identified Class 1 losses as shingle loss, vinyl siding loss, shingle and siding loss, as well as other Class 1 damage. All other classes of damage were also counted although the occurrence of damage other than shingle and siding loss was minimal in these communities.

The damage classification system used is an expanded version of the classification scheme used in previous manufactured home performance studies by McDonald et al, 1987 [5], and Levitan et al, 1993 [6]. The classification for overall damage was recorded as well as a classification for each category of damage. Multiple categories were recorded for damage that did not appear to be linked. Nearly all communities visited had heavy losses of the skirting around the base of the mobile homes; this was not considered as damage to the unit.

The overall results of performance of manufactured housing in the affected area are presented first, followed by a comparative presentation based on period of manufacture. Results for specific types of damage are then presented. Those damage categories include tree, anchorage, wall, and roof damage. The damage results from the quick surveys are then presented with particular attention to the shingle and siding loss.

DAMAGE ANALYSIS BY DAMAGE CLASS

Table 2 shows damage observed by damage class. All surveys are included in these results.

Table 2: Damage Summary by Damage Class

		Damage Class				
Community	Total # Units	0	1	2	3	4
Glen Meadow	26	7	15	2	2	0
Twin Oaks	58	21	37			
Savoy Rd.	10	7	2	1		
Autumn Acres	21	5	7	1	2	6
Stewart Rd.	21	9	7	1	1	3
Devall Rd.	18	4	4	5		5
Forrest Dr.	49	14	27	7	1	
Charley Hardison's	4	1	3			
C-Port	10	10				
Country Corner	34	18	14	1	1	
Patton St., Sulphur	80	45	31	3	1	
C Wait, Lake Charles	52	23	27	1	1	
Totals	383	164	174	22	9	14
% Units per Damage Class		42.8	45.4	5.7	2.3	3.7

Of the 383 units surveyed in the 12 communities 42.8% had no visible or very minor damage (Class 0). Minor damage (Class 1) was detected in 45.4% of the units surveyed, moderate damage (Class 2) in 5.7%, severe damage (Class 3) in 2.3% and 3.7% of the units were destroyed (Class 4). 11.7% of the units had significant damage, i.e., moderate to total damage (Class 2-4).

Class 4 damage occurred in only three of the communities, Autumn Acres, Stewart Rd., and Devall Road. Autumn Acres and Stewart Rd. are both communities with older, mostly poorly maintained and inadequately anchored mobile homes. Both communities had only pre-1994 and pre-1974 manufactured housing and were located near Toomey Louisiana, where the highest wind speeds of all the survey areas from Hurricane Rita were estimated to have occurred. Autumn Acres also was heavily treed within the community and suffered the most severe tree damage with 7 units damaged, 6 of those at Class 3 or 4 levels. Only Glen Meadow had a higher occurrence of tree damage but the damage intensity was much lower with only one unit suffering Class 3 damage. Some of the units on Devall Rd. were also older poorly maintained and inadequately anchored units. Devall Rd. was also located within the area of highest estimated wind speeds areas surveyed. Of five Class 4 damaged units on Devall Rd., 4 were pre-1974 and three of those suffered a total superstructure collapse, two of which had presumably first fallen completely off the support blocks. The forth pre-1974 unit that suffered Class 4 damage had lost the entire roof structure and had also fallen off the blocks. The fifth unit that was completely destroyed was an inadequately anchored pre-1994 unit that had rolled onto the roof, twisted and lost much of the walls.

DAMAGE ANALYSIS BY DAMAGE CATEGORY

Table 3 details the damage in each community by damage category. Only communities having detailed surveys were included in this analysis, so Patton St. and C Wait were not included. In some cases the total for the categories exceed the total numbers of units because many units suffered more than one type of damage. Overall damage rates should be considered only while viewing table 2.

Table 3: Damage Summary by Damage Category

		Damage Category					
Community	Total # Units	Anch.	Wdow	Walls	Roof	Tree	Impact
Glen Meadow	26	1	7	10	3	10	0
Twin Oaks	58	0	1	24	18	2	2
Savoy Rd.	10	0	0	3	0	0	0
Autumn Acres	21	6	4	6	2	7	0
Stewart Rd.	21	5	0	5	6	2	0
Devall Rd.	18	8	3	9	3	0	0
Forrest Dr.	49	2	3	16	24	7	0
Charley Hardison's	4	0	0	1	3	0	0
C-Port	10	0	0	0	0	0	0
Country Corner	34	3	5	8	9	0	0
Totals	251	25	23	82	68	28	2
% of Total per Damage Category		10.0	9.2	32.7	27.1	11.2	0.8
Total # of Damaged units	155						

Anchorage failure affected 10% of the 251 total units included in this analysis and constituted 16.1% of the failures. The high damage rates for walls and roofs are influenced by the heavy loss of vinyl siding and asphalt shingles experienced by newer units. Those damage rates were 32.7% of all units for walls and 27.1% of all units for roofs. Of the units that had damage, 52.9% had damaged walls and 43.9% had damaged roofs. Tree damage affected 11.2% of all the surveyed units or 18.1% of the damaged units. Impact other than trees was relatively light with 0.8% of all units affected or 1.3% of the damaged units. Impact damage was typically assumed when puncture holes or creases in walls appeared to have been caused by impact although no obvious debris from the impact were still present. Impact damage was recorded for only two units.

DAMAGE BY AGE OF MANUFACTURED HOUSING

Damage data were sorted by date of manufacture then displayed by class and category in Table 4. While the post-1994 unit results show a high 62.8% of units damaged, it is predominately Class 1 damage and in the case of those newer models it will be shown later that the Class 1 damage is primarily shingle and siding loss. The Class 1 damage for the post-1994 units is 95% of the total damage. The wall and roof category values of 33.9% and 35.4% respectively further indicate this. The category values are expressed as a percentage of all units in the group and do not have a sum of 100% or the same value as the overall percentage since not all units were damaged and some units were recorded as having multiple categories of damage but only counted once in the overall category. The pre-1974 group does however coincidentally add up to 100%.

Table 4: Damage Analysis by Class and Category for all Detailed Surveys

		Damage Overall	Ties	Windows	Walls	Roof	Tree	Impact	% of Total by Class
Post 1994 Manufactured Housing									
127 Units	Class 0 (Undamaged)	48							37.8
	Class 1	75	0	5	43	44	7	2	59.1
	Class 2	3	0	0	0	1	3	0	2.4
	Class 3	1	1	0	0	0	0	0	0.8
	Class 4	0	0	0	0	0	0	0	0.0
	Total Damaged	79	1	5	43	45	10	2	62.2
	% of Total by Damage Type	62.2	0.8	3.9	33.9	35.4	7.9	1.6	
1974-1994 Manufactured Housing									
64 Units	Class 0 (Undamaged)	29							45.3
	Class 1	20	3	9	13	11	4	0	31.3
	Class 2	9	6	0	6	2	1	0	14.1
	Class 3	2	0	0	0	0	2	0	3.1
	Class 4	4	1	0	1	1	2	0	6.3
	Total Damaged	35	10	9	20	14	9	0	54.7
	% of Total by Damage Type	54.7	15.6	14.1	31.3	21.9	14.1	0.0	
Pre 1974 Manufactured Housing									
60 Units	Class 0 (Undamaged)	19							31.7
	Class 1	21	6	9	13	6	2	0	35.0
	Class 2	6	7	0	5	1	2	0	10.0
	Class 3	4	0	0	0	0	3	0	6.7
	Class 4	10	1	0	1	2	2	0	16.7
	Total Damaged	41	14	9	19	9	9	0	68.3
	% of Total by Damage Type	68.3	23.3	15.0	31.7	15.0	15.0	0.0	

The 1974-1994 group shows a decline in total damaged units when compared to the post-94 group with an overall damage percentage of 54.7, the damage by class, however shows a sharp rise in damage intensity. Total destruction occurred in 6.3% of the units verses zero for the post-94 group. While Class 1 damage is less, Classes 2, 3, and 4 damage have increased. It should also be noted that Class 1 damage to the older units is typically more severe since pulling away of the metal siding commonly used on the older units exposes the insulation and the inner wall board to water intrusion while loss of the typically used siding or shingles on a newer unit exposes only the underlying sheathing. While exposure of the sheathing could lead to water damage it is likely it would be less severe.

The pre-1974 group experienced damage to 68.3% of the units in the group. There was also an increase in the damage intensity, as indicated by the classes of damage. Total destruction occurred in 16.7% of the units and all other classes of damage were higher than both newer groups except for Class 1 when compared to the post-1994 group for the same reason previously mentioned, and the Class 2 damage when compared to the 1974-1994 group. Class 3 and Class 4 damage in the pre-1974 group are both more than double the values for the 1974-1994 group. The bar chart in Figure 5 compares the overall damage by class and age.

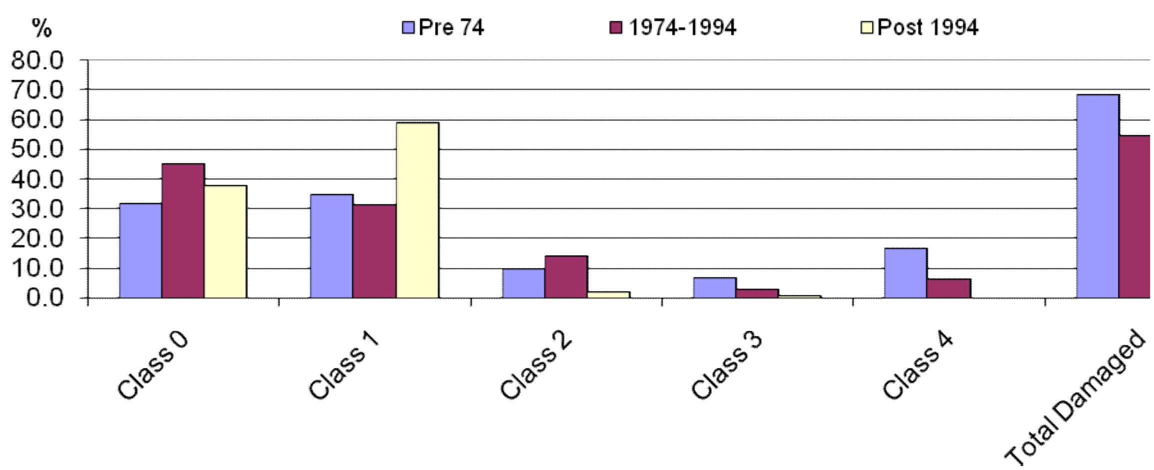

Figure 5: Damage Analysis by Class and Category for all Detailed Surveys

Manufactured housing age had a strong influence on the extent of tree damage sustained. Pre-1974 and 1974-1994 group units have 15% and 14.1% of all units damaged which is nearly double the 7.9% damage that occurred in the post-1994 group. Damage intensity can also be seen to increase with the group age. A review of table 1 will show that older units were more exposed to tree damage because the communities with the most trees were usually those with the older units. Typically the newer communities had fewer trees and the trees were smaller and not as close to the housing.

Manufactured housing age had a strong influence on the extent of damage from anchorage failure. Again, the occurrence of damage increased as the group age increased, with the post-1994 group suffering only one case of Class 3 damage in a total of 127 units. The pre-1974 units had a 23.3% damage rate which was 34.1% of the units that sustained damage. Only one unit each in the 1974-1994 and post-1994 groups received Class 3 or 4 damages (rolling onto side or roof). Each of these units had either no anchors or was poorly anchored.

Table 5 compares wall and roof damage by age group. The post-1994 Class 1 damage is further divided into moderate shingle or siding loss, light shingle or siding loss, and other Class 1 damage. Light loss was recorded for those units having less than 100 sq. ft. of loss while moderate loss was recorded for those units that lost more than 100 sq. feet. The typical loss patterns were either a small section or the loss of the majority of one wall for siding, and either a scattered loss of shingles or near complete loss of the entire windward side of the roof for shingles.

The majority of damage to the roofs and walls of the post-1994 units was shingle and siding loss with 54.4% of all damage being wall damage and 35.4% of all damage being roof damage. Most of that damage recorded was light siding or shingle loss and those values should be considered when looking at the levels of overall and Class 1 damage that was previously shown in Table 4. Wall damage for the 1974-1994 group was similar to the pre-1974 group while roof damage was interestingly greater for the 1974-1994 group than the older group. Both the pre-1974 and 1974-1994 groups typically have metal walls and roofing.

Table 5: Damage to Wall Cladding and Roofing

		Damage Overall	Walls	% of Total	% of Damaged	Roof	% of Total	% of Damaged
Post 1994 Manufactured Housing								
127 Units	Class 0 (Undamaged)	48						
	Light Siding or Shingle	0	32	25.2	40.5	35	27.6	44.3
	Moderate Siding or Shingle Loss	0	6	4.7	7.6	2	1.6	2.5
	Other Class 1 Damage	75	5	3.9	6.3	7	5.5	8.9
	Class 1 Totals	75	43	33.9	54.4	44	34.6	55.7
	Class 2	3				1	0.8	1.3
	Class 3	1						
	Class 4							
	Total Damaged	79	43	33.9	54.4	45	35.4	57.0
1974-1994 Manufactured Housing								
64 Units	Class 0 (Undamaged)	29						
	Class 1	20	13	20.3	37.1	11	17.2	31.4
	Class 2	9	6	9.4	17.1	2	3.1	5.7
	Class 3	2						
	Class 4	4	1	1.6	2.9	1	1.6	2.9
	Total Damaged	35	20	31.3	57.1	14	21.9	40.0
Pre 1974 Manufactured Housing								
60 Units	Class 0 (Undamaged)	19						
	Class 1	21	13	21.7	31.7	6	10.0	14.6
	Class 2	6	5	8.3	12.2	1	1.7	2.4
	Class 3	4						
	Class 4	10	1	1.7	2.4	2	3.3	4.9
	Total Damaged	41	19	31.7	46.3	9	15.0	22.0

CONCLUSIONS

Wind speeds in all surveyed areas did not reach design levels, so an ultimate test of how well the Post-1994 homes meet the new standard was not forthcoming. Wind pressure is a function of the square of the velocity, Table 6 show the relative wind pressures experienced in the surveyed communities as compared to the pressure at design wind speed for that community. HUD Design wind pressures were not reached in any of the survey areas.

Table 6: Damage to Wall Cladding and Roofing

1 minute sustained (AOML)	Fastest Mile (HUD)	Wind Pressure % of 100 mph	Wind Pressure % of 110 mph	Location	HUD Zone
80	82		55.6	Belle Chasse, Port Fourchon	3 (110 mph)
75	77	59.3	49.0	Vinton, Toomey, Hackberry	2 (100 mph)
70	72	51.8		Sulphur	2 (100 mph)
65	66	43.6		Lake Charles	2 (100 mph)
60	60	36.0			
96	100	100.0		Zone II Design Wind Speed	
105	110		100.0	Zone III Design Wind Speed	

The frame structure of the newer units was not visibly damaged in any case including one where a poorly anchored unit was turned over on its side. No racking or superstructure separation was seen in any post 1994 unit.

Older units were more likely to sustain tree damage. This is probably a result of older mobile homes typically having higher exposure to trees.

Superficial damage was more common on the post-1994 units than in any of the other age groups. This is due to the building practices used in the newer units, where the walls and roof are first sheathed, usually with plywood or OSB, then covered with vinyl siding for walls and asphalt shingles on the roof. The older models typically used sheet metal siding and roofing. Loss of the vinyl siding and roof shingles occurred at a higher rate than loss of metal siding and roofing. However, the consequences of shingle and vinyl siding loss are much less than medal cladding loss on older homes. This is because the post-94 homes have plywood or OSB sheathing beneath the cladding which remained in place, whereas loss of metal cladding exposes the insulation and wall/roof cavities. Cladding loss on the newer units was not uniform between units in the same exposures indicating possible material, construction practice or quality control problems. One possible explanation for inconsistent performance may be quality of on-site cladding installation on end walls of double wide units.

Attempting to maintain an approach consistent with previously conducted similar damage assessments presented a problem with the classification of shingle and siding loss that is typical of post-1994 manufactured housing. Previous studies defined Class 1 siding damage as “minor pulling away of siding with attendant water damage”. Due to a lack of residents in the homes at the time the surveys were conducted it was not possible to get information on the rate of occurrence of water damage on post-1994 Shingle and siding clad units with cladding loss. Presumably, such occurrences of water damage would be a function of duration and intensity of rainfall after cladding loss, but without further study it is assumed to occur at a rate less than that of units with pulled away metal sheathing/siding. Cost of repairs was outside the scope of the current survey but would offer guidance on the proper classification of cladding damage. Follow up surveys of some homes that suffered cladding damage, including homeowner interviews on repair costs might be useful. A detailed study of the causes of cladding failure could help reduce the rate of occurrence in homes built in the future.

ACKNOWLEDGEMENT

The analysis makes use of wind field data from Hurricane Katrina initially gathered by field researchers from Texas Tech University, the Florida Coastal Monitoring Program (FCMP) and others. The FCMP is a joint venture that includes participants from Clemson University, the University of Florida and Florida International University and is sponsored by the Florida Department of Community Affairs. Subsequent analysis of the wind field data was performed by the NOAA Hurricane Research Division and the Atlantic Oceanographic and Meteorological Laboratory. The data sharing among these research groups is gratefully acknowledged.

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