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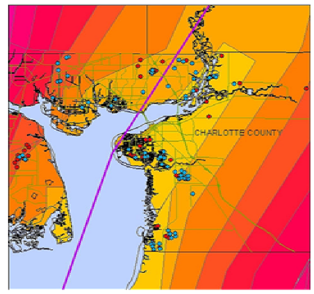

Post 2004 Hurricane Field Survey – an Evaluation of the Relative Performance of the Standard Building Code and the Florida Building Code

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FLORIDA BUILDING COMMISSION

Civil & Coastal Engineering

UNIVERSITY OF FLORIDA

Post 2004 Hurricane Field Survey
An Evaluation of the Relative Performance of the Standard Building Code and the Florida Building Code

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Table of Contents

Introduction

This report relays the methodology and presents results of an ongoing study of the performance of residential structures in the State of Florida. Specifically, site built single family homes constructed after Andrew-related changes to the standard building code were in effect were targeted for a detailed investigation of damage as a result of the 2004 hurricane season. The purpose of this study is to provide a quantitative statistical comparison of the relative performance of homes built between 1994 and 2001 with those built after the 2001 Florida Building Code replaced the Standard Building Code.

Ample anecdotal evidence after Hurricane Charley indicates that homes built to the current code standards performed well in general when compared with older construction. Despite improved performance, it was observed that failure of critical components (e.g., roof cover and soffits) was still significant in new homes. Damage studies in the immediate aftermath of the 2004 storms were not designed to provide a statistically relevant comparison of relative damage levels among homes of varying age, peak wind exposure, and region of Florida. In an effort to determine whether the Florida building code resulted in significant reductions in vulnerability and loss, the Florida Building Commission initiated this study to *quantify* relative performance of residential structures over a range of ages, construction types, and peak wind zones.

Methodology

This evaluation is being accomplished through a systematic survey of homes built from 1994 to 2004 in the areas that experienced the highest wind speeds from the 2004 season's storms (Charlotte, St. Lucie, and Escambia counties). A statistically significant number of homes within a set of target structures were surveyed in these regions in order to define correlations between damage and age. These relationships are referenced to maximum 3-second gust wind speed via wind swath maps.

The selection of study subjects was designed based upon two goals:

1) Determine the *average* performance of post 1994 residential structures
2) Mimic the housing stock distribution using a stratified sampling procedure

These goals lead to a sampling strategy that chooses subject homes based only on their age of construction, construction details (e.g., hip vs. gable, tile vs. shingle), and maximum wind exposure. No prior knowledge of the level of damage (if any) was used in the selection process. Thus the resulting statistics of damage represent the performance of the *average* house rather than only severely damaged houses.

A GIS (Geographic Information System)-based database of home construction type and age (includes all homes within the target counties) was overlaid with hurricane wind swath maps of the 2004 storms (maps of maximum 3-second gusts) to randomly select the homes to be surveyed within the desired stratifications. Survey teams have the study subjects assigned to them by address before they are in the field to guarantee randomness and mitigate observational bias. The structures are evaluated with a 30 minute damage survey by trained engineering students and faculty. Electronic handheld data recorders (PDAs with customized software) are used to conduct the surveys, and data is transferred to a central Access database.

Evaluation

A survey was constructed to elicit quantitative information regarding the performance of the study subjects. The surveys are administered in person by trained teams documenting homeowner provided responses regarding level of damage, repair details and costs, and construction type. A structural investigation is also conducted to provide details of construction not evident by sight inspection and typically beyond homeowner knowledge. Extensive photographic documentation is taken with each survey.

The survey also elicits information on homeowner behavior days before a hurricane impact. This helps to determine factors that may influence both structural vulnerability and emergency management. For example, purchase and use of mitigation measures, and evacuation behaviors.

Structural Performance Evaluation

The survey consists of the following evaluations:

- GPS location
- Exposure (surrounding terrain)
- Orientation of home relative to North
- Openings (windows and doors, type and damage)

- Garage door (type, pressure rating and damage)
- Roof cover (type and damage)
- Soffit (type, size and damage)
- Attachments (type and damage: e.g. pool cage, carport, lanai)
- Interior water penetration (ceilings, doors, walls, windows)
- Roof construction (sheathing type and thickness; fastener type, size and spacing; roof to wall connections type and frequency)
- Window protection use and effectiveness
- Loss recovery from insurer

Behavioral Evaluations

Homeowner behavior was also documented with regard to evacuation and mitigation in the 2004 season, as well as intentions for future seasons:

- Homeowner impression of wind speeds, gust vs. sustained and storm category
- Evacuation (if, why, when and where)
- Remain at home: why and personal experiences
- Window protection (owned? what type? was it applied prior to storm(s)?)
- Future actions regarding evacuation (if, why or why not, where, when)
- Future actions regarding window protection (if and what type)

Data Collection Method

Survey data is gathered with a foundation of redundancy. Documentation in the form of digital pictures and hand sketches of the home are combined with electronic data entered into a handheld computer (PDA). The PDA electronic survey is designed to document the homeowner's actions during the storm, any protection applied to the home, any damage occurring to the home, roof construction and cost estimates for repair or replacement (insurance settlements). Pictures are taken at 45^o angles around the house perimeter, both facing and away to document the house and surrounding exposure. The distance of tree lines, other structures, topography, etc. from the home are also recorded using a laser range scope. A hand sketch of each elevation and the roof plan is made to aid the homeowner while indicating damage to the team. Each external window and door is also documented within the survey, including type, size, protection and performance (damage, breach, water penetration) during the hurricane.

All data is gathered through personal appointments with homeowners, and conducted during weekends from January through May of 2005 by faculty and students from the University of Florida, Florida A&M, Florida International University and staff at the Institute for Business and Home Safety.

Homeowner Contact

Each survey is scheduled prior to a given weekend. Information mailers with request for participation are sent to homeowners randomly selected using the stratified sampling procedure. Follow up calls are made to schedule appointments with those willing to participate. The cooperation is a random event, thus injecting further randomness to the subject selection.

Survey Dataset Demographics

Surveys were conducted on weekends from January through May of 2005. There were a total of 195 surveys conducted over three counties. This dataset consists of surveys of 126 homes in Charlotte County (Charley), 33 in St. Lucie County (Frances and Jeanne), and 36 in Escambia County (Ivan).

Figure A is a display of the randomly selected 126 Charlotte County survey samples. The wind swaths are displayed as peak 3-second gusts, in bands of 10 m.p.h., where the lightest band is 140-150 mph (zone 11, just south of the storm track), and surrounding bands are 130-140 (zone 10), etc. This wind swath was provided courtesy of Peter Vickery at Applied Research Associates. It can be observed that zones 8, 10 and 11 (110-120, 130-140, 140-150 m.p.h.) were selected for stratification for Charlotte County. Zones 10 and 11 represents the highest wind zones, and contain 104 samples. Zone 8 was also selected (with 22 surveys) to allow a consistent peak wind speed reference when comparing Charlotte County damage to those homes impacted by the most severe winds of Ivan, Jeanne and Frances (all of which had maximum 3-second gusts ~ 120 m.p.h.).

Figure B shows the 36 samples collected in Escambia County, and Figure C shows those collected for St. Lucie County. In both cases only the highest wind swath of 110 – 120 mph (zone 8) were targeted for surveys. The Fig. C highest wind swath shown is the region where both Frances and Jeanne overlap with 110 – 120 mph peak three second gusts.

Table 1 presents the breakdown of survey demographics by age group, wind zone and region. Many of the results in this report are provided as a function of three groups of year of construction. 1994 – 1998, 1999 – 2001, and 2002 – 2004. The first two groups represent the 'old' code, while the third is referred to as 'new' code. The intent of separating the 'old' group into two sub-groups is to help delineate aging effects from code change induced differences in performance.

Results

Results are presented in separate sections as indicated in the Results Table of Contents (Table 2, page 5). Each section includes a description of the figures as well as results interpretation. Table 3 is a List of Figures, and provides the topic and sampling stratification for each figure in this report.

Table 1: Demographics of surveys collected

<table>
<tr><td colspan="2" rowspan="2">Total # samples = 195</td><td colspan="3">Charley
Total = 126</td><td>Ivan
Total = 36</td><td>Frances / Jeanne
Total = 33</td></tr>
<tr><td>Zone 8
110 - 120</td><td>Zone 10
130 - 140</td><td>Zone 11
140 - 150</td><td>Zone 8
110 - 120</td><td>Zone 8
110 - 120</td></tr>
<tr><td rowspan="2">Old code
SBC</td><td>'94 – '98</td><td>1</td><td>22</td><td>10</td><td>10</td><td>5</td></tr>
<tr><td>'99 – '01</td><td>10</td><td>23</td><td>14</td><td>10</td><td>12</td></tr>
<tr><td>New code
FBC</td><td>'02 – '04</td><td>11</td><td>12</td><td>23</td><td>16</td><td>16</td></tr>
</table>

Table 2: Results Table of Contents

Category	Figure numbers	Page numbers
Observations: Summary of Findings		8 – 10
Water penetration	1 - 8	11 – 15
Window protection / window damage	9 – 14 & Table 3	16 – 20
Soffit damage	15 - 23	21 - 25
Roof cover damage	24 - 42	26 – 36
Attic / Roof attributes	43 - 54	37 - 43

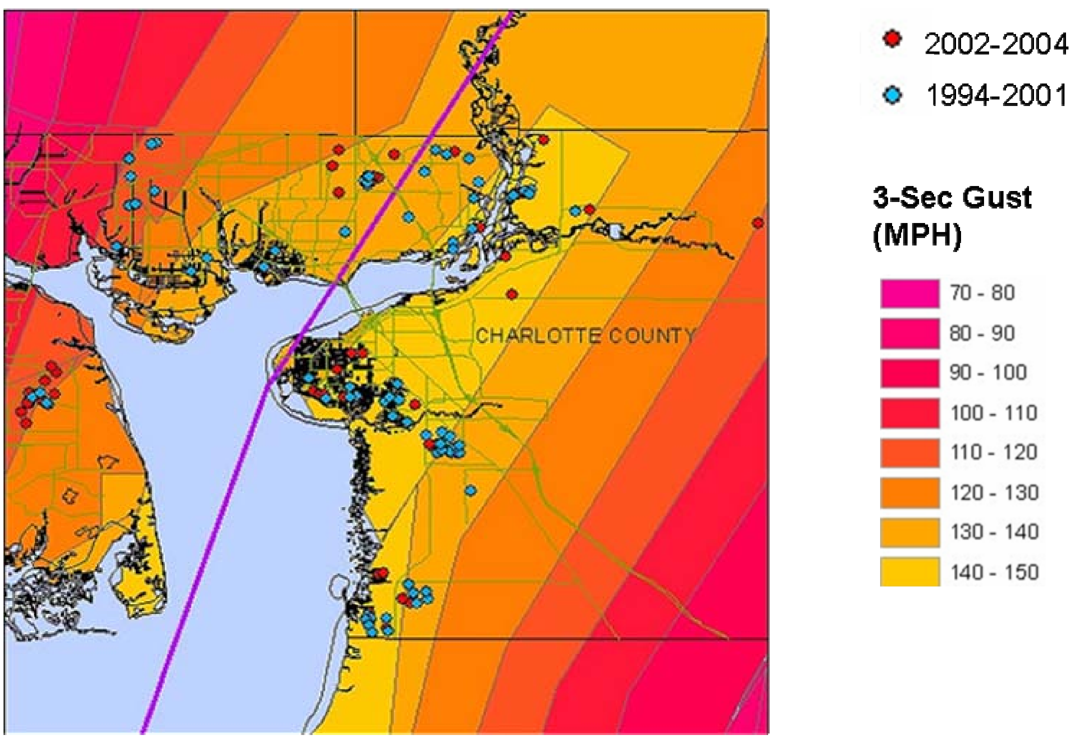

Figure A: Charley wind swaths (courtesy of Peter Vickery, Applied Research Associates) and location of randomly selected survey subjects.

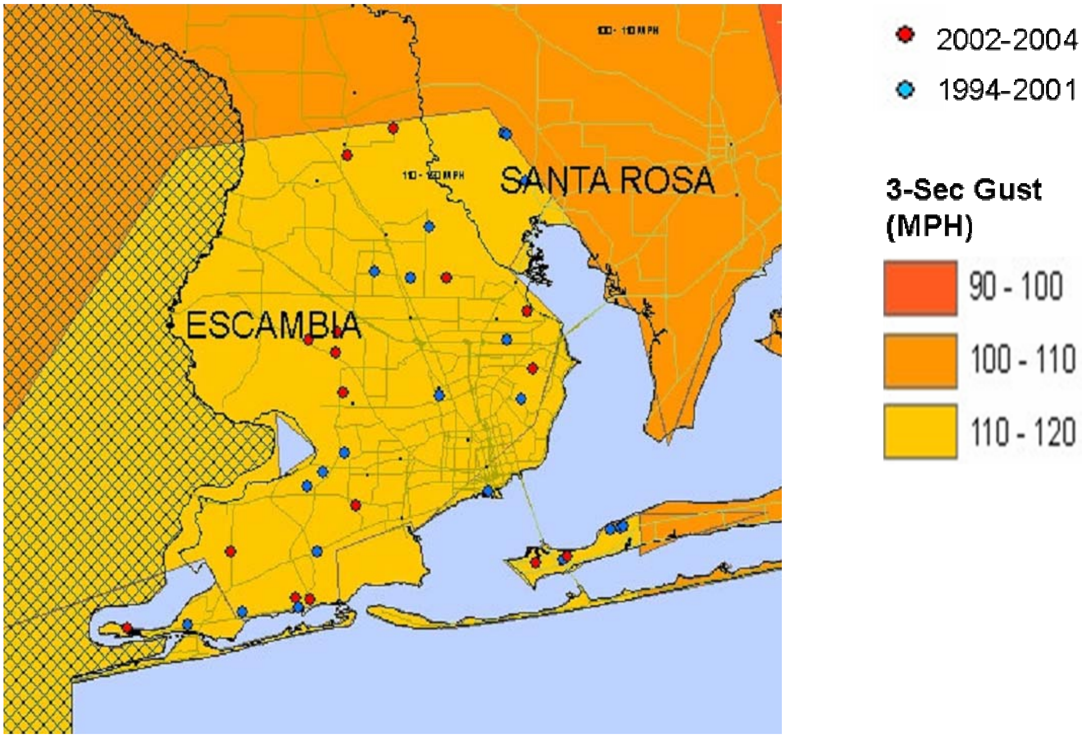

Figure B: Ivan wind swaths (courtesy of Peter Vickery, Applied Research Associates) and location of randomly selected survey subjects.

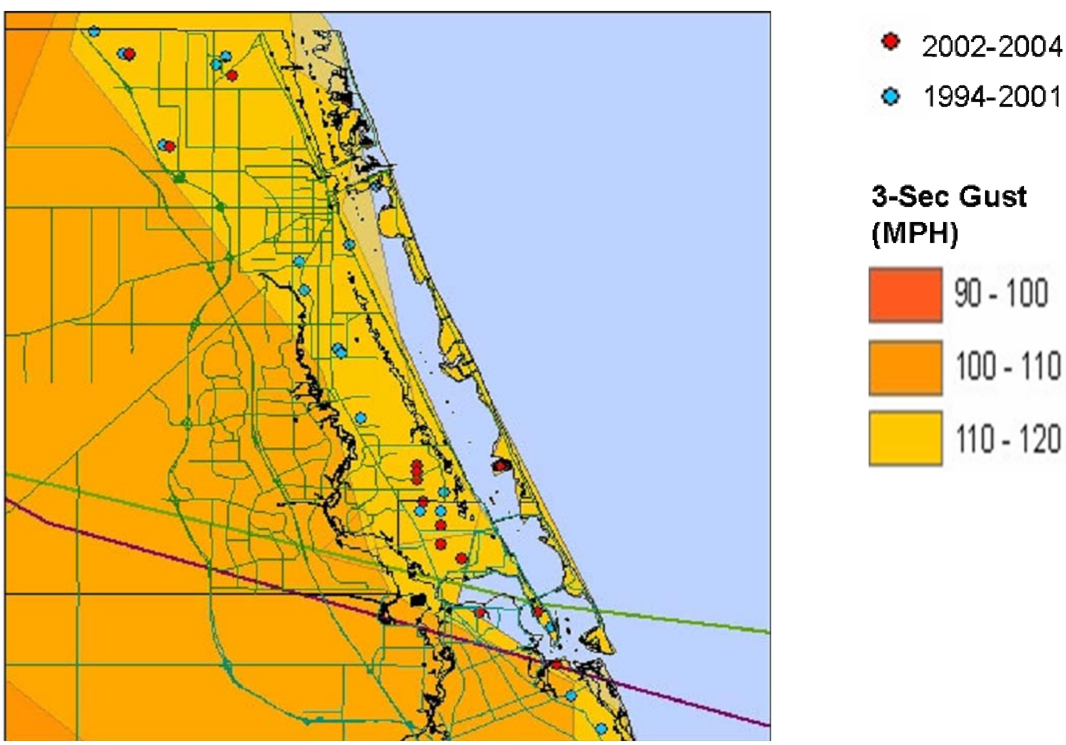

Figure C: Frances / Jeanne wind swaths (courtesy of Peter Vickery, Applied Research Associates) and location of randomly selected survey subjects.

Table 3: List of Figure

* options: C (Charley, Charlotte County), F&J (Frances and Jeanne, St. Lucie County), I (Ivan, Escambia County)
** options: 8 (110 – 120 mph), 10 (130 – 140 mph), 11 (140 – 150 mph), All refers to 8, 10, 11 together
*** options: 94 – 98 (SBC), 99 – 01 (SBC), 02 – 04 (FBC), All refers to 94 - 04

Observations: Summary of Findings

This section presents a summary of major findings from the results. More detailed discussions of results are found in the sections shown in the Table 2 Table of contents (page 5)

- ***Structural Damage:*** The most significant observation is a lack of structural damage to any of the homes surveyed, even in the highest wind zones of Hurricane Charley. There were no cases of roof sheathing failure, wall failure, or roof to wall connection failure in any of the surveyed homes. Roof sheathing failure was observed on homes of pre-1994 construction by teams in the field immediately after all four 2004 hurricanes. However, these observations were not documented statistically, as pre-1994 homes were not a part of this survey study. It is significant that none of the post-1994 construction surveyed suffered serious damage other than roof cover loss, water penetration, soffit loss, and window damage.

- ***Garage and entry door failure:*** None of the surveyed homes suffered garage door damage beyond window cracks, dents and finish scuffing from debris. As was the case noted with structural damage, field teams did observed many cases of severe garage door damage on pre-1994 homes. These observations were made before this statistical survey project was conducted. They are therefore anecdotal, but none the less indicate improved performance of wind rated garage doors. Several of the surveyed homes did suffer breach of the entry doors from wind pressure. Each of these few cases involved double entry doors. None of the single entry doors surveyed were forced open by wind pressure. Anecdotal field observations immediately after hurricane Charley indicate that double entry doors are an issue that should be addressed in future building code changes.

- ***Water penetration by code:*** It is not clear from Figures 1 – 8 that the FBC provides any improvement in preventing water penetration. The oldest age group shows a higher likelihood for ceiling damage, both in the interior and near exterior walls (Fig.8). This is most likely due to a combination of more soffit and roof cover loss for the older homes.

- ***Mitigation - homeowner future use:*** Table 4 provides percentages of protection by type for both the 2004 season and homeowner intent for future seasons. It is encouraging to see that the no protection category drops significantly from the 2004 season to the future intent of the homeowner.

- ***Window vulnerability and Mitigation effectiveness – shutter use:*** Vulnerability of windows was found to be highly correlated to wind speed, window protection use, and the dominant roof cover type in the neighborhood. Damage is defined as the need for repair or replacement, but does not delineated between scratches, cracks and breach. Since the survey was conducted at least several months after the storms, it is not possible to distinguish pressure damage from debris damage. Figure 14 presents data for hurricane Charley wind zones 10 & 11 combined (130 – 150 mph 3-sec gusts). The vertical axis is the percentage of homes that suffered damage to at least one window. The horizontal axis delineates protected from unprotected windows in three sections, overall, tile neighborhoods, and shingle neighborhoods. The use of window protection cut the likelihood of window damage by close to 65% in all cases. Homes in tile neighborhoods are more likely to experience window damage compared to homes in shingle neighborhoods by a factor of 2. The upcoming sections on roof cover performance indicate that tile roofs are more likely to fail than shingle roofs in the highest wind zones (figures 23, 24, 28, 29). Thus at least a portion of the increase in window failure in tile neighborhoods can be attributed to a higher availability of roof cover wind borne debris. It is clear that tiles are a major concern for window vulnerability when wind speeds are high enough to cause significant loss of roof cover. Companion results for wind zone 8 (110 – 120 mph 3-sec gust) show a very low probability of window damage for both protected and unprotected windows at this wind speed range. This low probability of window damage was also observed for the zone 8 survey subjects in Ivan, Frances and Jeanne.

- ***Soffit performance with age of construction:*** In Figures 21 & 22 a clear trend can be seen: increasing likelihood of soffit damage with increasing age of structure (only valid over the surveyed range 1994 – 2004).

- ***Shingle roof cover performance by region:*** Figures 32 – 34 compare performance of shingle roofs in the same wind swath (110 – 120 mph 3 second gust) in three regions. Charlotte County had a significantly lower percentage of houses with shingle damage (32% of surveyed houses had damage) compared with St. Lucie County (80%) and Escambia County (50%). Not only did a smaller percentage of homes suffer shingle damage in Charley, but those that did suffered less damage on average than those in the Ivan and Frances / Jeanne regions. The increased shingle damage in St. Lucie County is due in some part to the passage of two storms. The effect of the storms individually cannot be delineated from this data set.

- ***Shingle roof cover performance by wind speed:*** In the Charley impacted region, as wind speeds increase from 120 mph to 140 and 150 mph peaks, the percentage of shingle homes that suffered roof cover loss rose from 32% to 65% to 79% (Figure 26)), indicating a threshold wind speed for severe roof cover loss in the area of 120 mph 3 second gust.

- ***FBC improved performance – Shingle roof cover performance by age of construction:*** Figure 41 presents the performance of shingle roofs in Charlotte County in the highest wind zone. The figure shows a distinct difference in shingle performance by age, with significant quantities of shingle damage to the age group 1994 – 1998, less damage in 1999 – 2001, and even less in the FBC group 2002 – 2004. Specifically, every shingle house surveyed in Charley zone 11 built between 1994 and 1998 has shingle damage, all had at least 10% shingle loss, and most had between 25 and 50% loss. Conversely, 30% of shingled house in that same wind zone built after 2001 had no shingle damage, and the wide majority of those that had damage lost less than 5 % of their shingles.

- ***Tile roof cover performance:*** Figure 40 presents tile loss data for the highest Charley wind zone only stratified by 3 age groups (Figure 28 shows this data for all Charley wind zones combined). Very few surveyed tile roof homes of any age group suffered no cover damage. The quantity of damage did vary with age. Only 15% of 2002 – 2004 homes had tile damage exceeding 5%, indicating that the vast majority of new homes suffered only ridge cap loss (with only a few exceptions). Among the 1999 – 2001 group, 60%

had over 5% damage, 44% over 10% damage, and 22% over 25% damage. Among the 1994 – 1998 group, 60% of the samples had damage quantity in the range of 6-25%. Overall this indicates a much higher probability of field tile loss in homes built 1994 – 2001 compared to new construction.

- ***Code compliance – roof to wall connection:*** Figure 42 shows the roof to wall connection frequency stratified by region and year of construction as a percentage of those surveyed homes that had a connection in place at every truss. Charlotte County showed the highest compliance of a connection at every truss with 95%, while St. Lucie and Escambia Counties dropping to 92% and 83%, respectively. The oldest construction age group (1994 – 1998) consistently has the lowest compliance with St. Lucie County the lowest rate at 65%. As noted previously, however, there were no observed cases of roof to wall connection failure for any of the survey subjects.

- ***Code compliance – sheathing fastener field spacing:*** Figures 51 – 53 present sheathing fastener field spacing stratified by age group for Charlotte, St. Lucie and Escambia Counties, respectively. All three regions show increasing conformity to six inch field spacing with newer construction. Charlotte County shows a significant percentage of FBC construction with spacing closer than six inches. Only a few cases of FBC construction had spacing greater than six inches. 33% of the homes built between 1994 and 1998 had a field spacing of 10 inches in St. Lucie County, and 75% of that age group had eight inch spacing in Escambia County. Charlotte County had the largest percentage of field spacing at six inches or less over all age groups sampled (1994 – 2004).

Recommendations: Outstanding Performance Issues in the FBC

The performance of homes built to the FBC showed improvements over those built to the SBC. Aging vs. code change effects are difficult to delineate (e.g. shingle performance), thus a more specific quantification of improved performance is not possible from this dataset.

A summary of successes in terms of performance and mitigation include:

- The structural integrity (walls, sheathing) of post 1994 construction was maintained in all survey subjects (highest wind gusts of up to 150 mph)
- 110 mph wind rated shingle roofs performed very well
- None of the wind rated garage doors failed
- The use of window protection showed a statistically significant reduction in window failure, justifying the application of the wind borne debris regions along Florida's coasts

A summary of issues to consider for future modifications to the FBC

- The performance of tile roof cover in conjunction with the quantifiable increased vulnerability of windows in tile neighborhoods indicates a need to address the attachment requirements for tile roof cover
- Water penetration was an issue in both SBC and FBC construction
- Soffit failure was significant in FBC construction, leading to water intrusion
- Anecdotal evidence suggests that the integrity of double entry doors is suspect

Observations: Detailed Presentation of Statistical Data Analysis

The remainder of this report discusses the statistical analysis of the collected data in further detail than was provided in the summaries in the previous section. Refer to Table 3 (page 7) for a detailed list of topics.

Water Penetration

Figures 1 – 8 present the percentage of surveyed homes in which homeowners indicated water penetrated the home. Minor and major water damage is grouped together, as well as points of entry. Figures 1 – 4 present percentages delineated by the age group of the structure for all Charley homes, and by wind zones 8, 10 & 11 respectively. Results from Frances / Jeanne and Ivan are in Figures 5 & 6. Figure 7 directly compares the three impacted Florida regions for comparable wind speeds. There are significant regional differences in water penetration, with Charlotte County showing the least percentage of homes with water penetration (in wind zone 110 – 120 mph). This is partially explained by the very quick translation speed of Charley in comparison with the other three storms, thereby reducing the likelihood of long and heavy rainfall.

Figure 8 breaks water penetration down into different points of entry using the data from all storms and surveyed wind zones (see Table 1 for total survey demographics). The oldest age group shows a higher likelihood for ceiling damage, both in the interior and near exterior walls. This is most likely due to a combination of more soffit and roof cover loss for the older homes.

Note that there is considerable overlap in the categories in Figure 8. That is, any given subject home may have more than one kind of water penetration. Therefore the percentages provided for any of the three age groups add to greater than 100%. For example, 55% of the homes in the oldest age group did not report water penetration, 23% had water penetrate through windows, 27% had ceiling damage near exterior walls, 25% ceiling damage at interior portions of the ceiling, etc. The sum exceeding 100% indicates homes with multiple categories.

It is not clear from Figures 1 – 8 that the FBC provides any improvement in preventing water penetration. There is no uniformly clear reduction in the percentage of home that experienced water penetration as a function of age group.

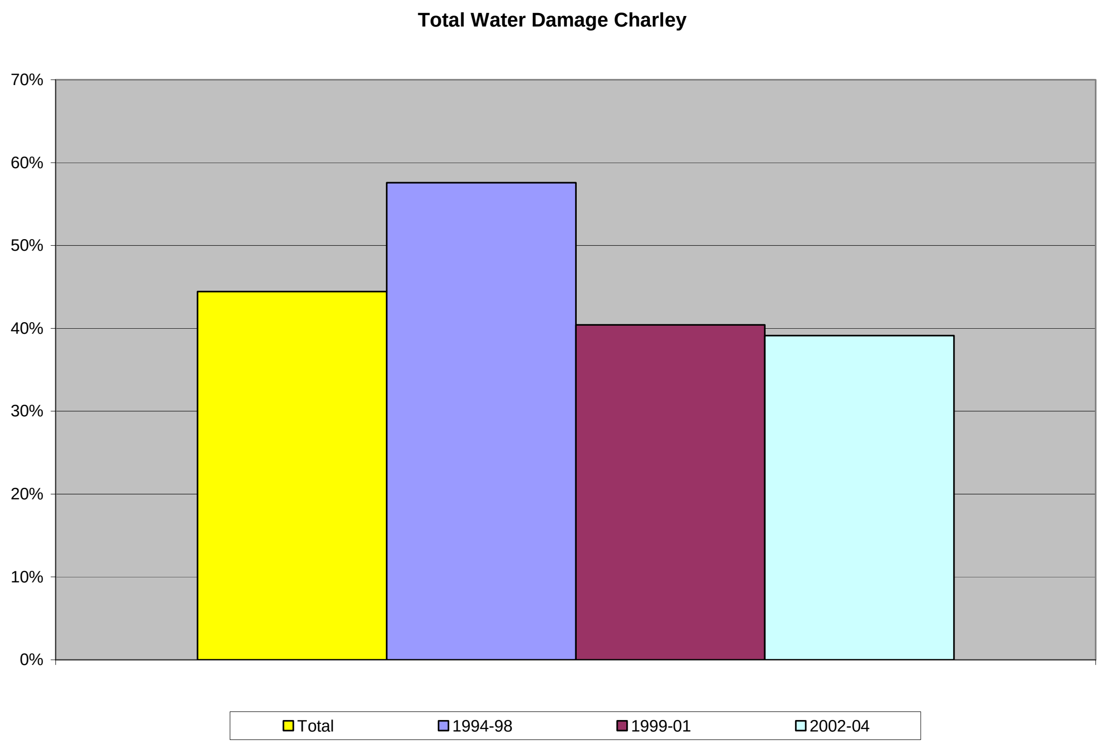

Figure 1: % of Homes with water penetration, all data for Charley

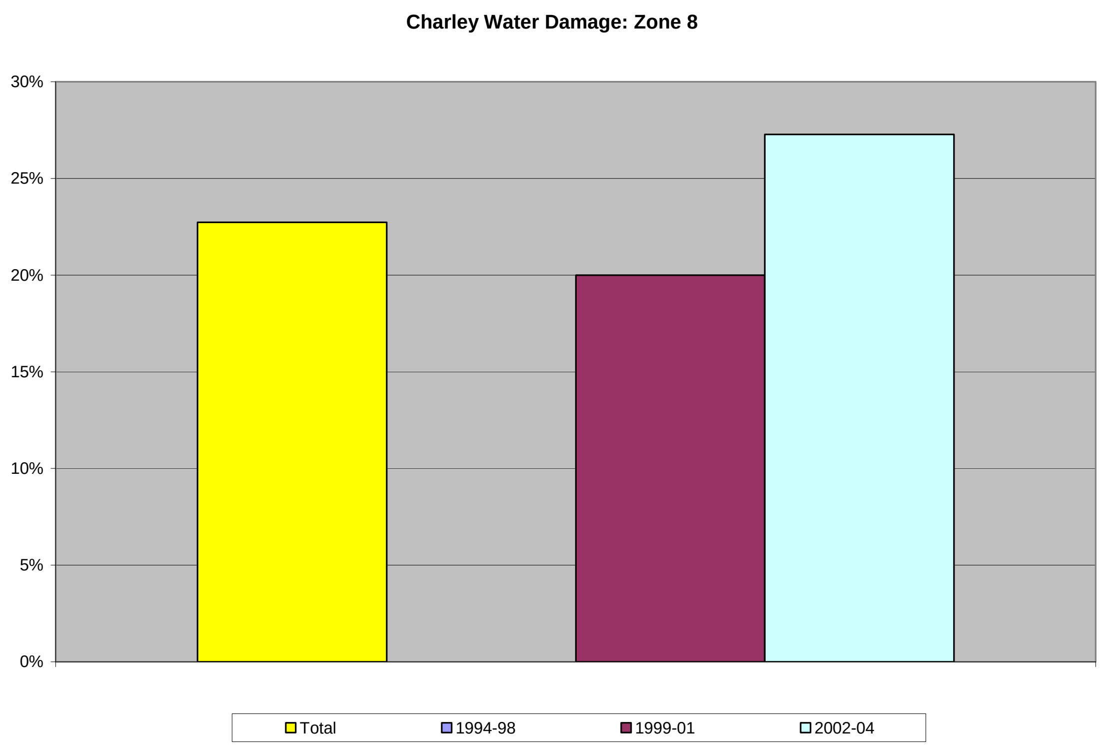

Figure 2: % of Homes with water penetration, Charley zone 8

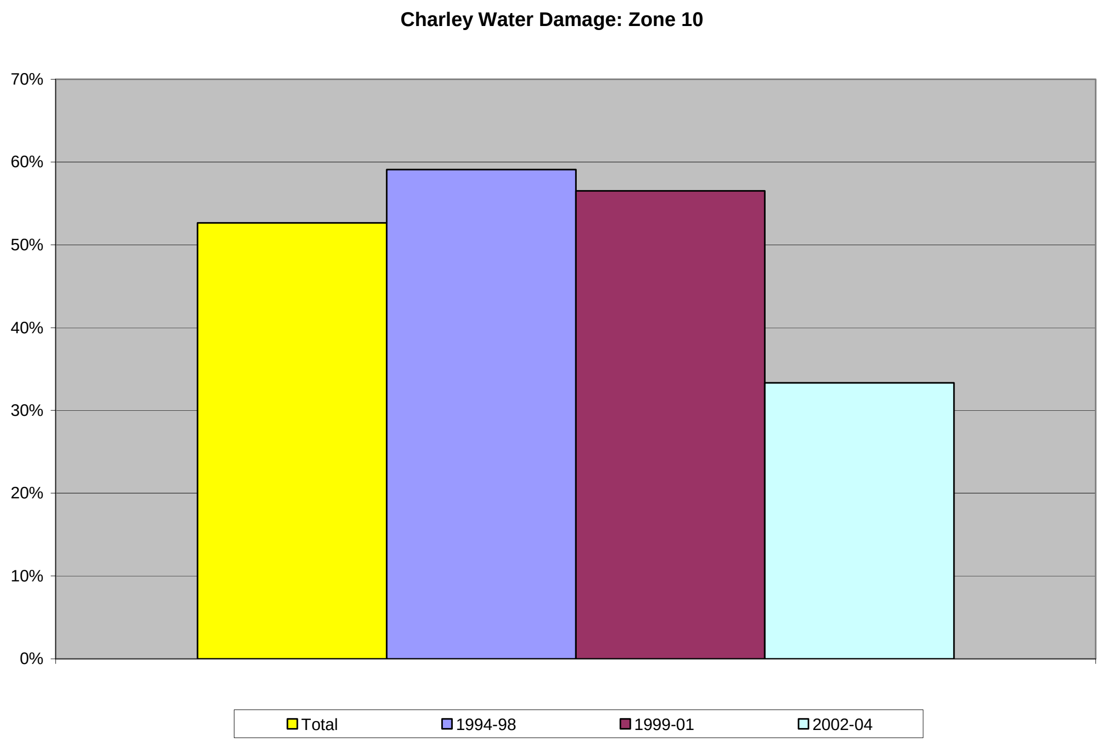

Figure 3: % of Homes with water penetration, Charley zone 10

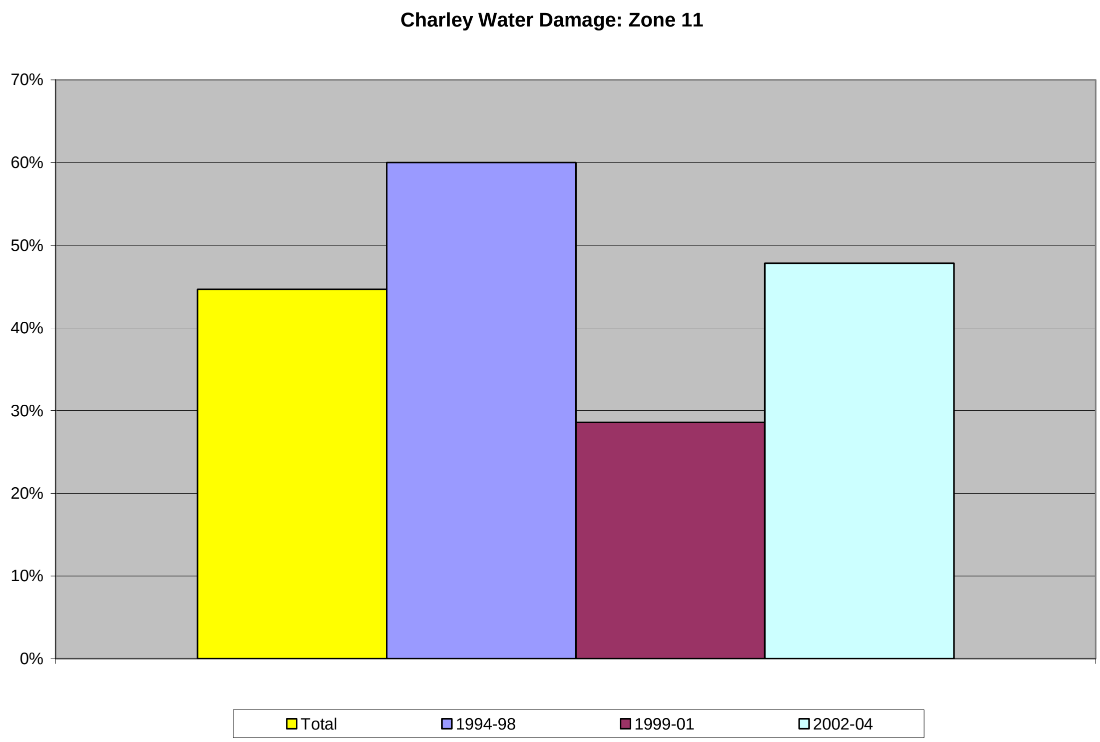

Figure 4: % of Homes with water penetration, Charley zone 11

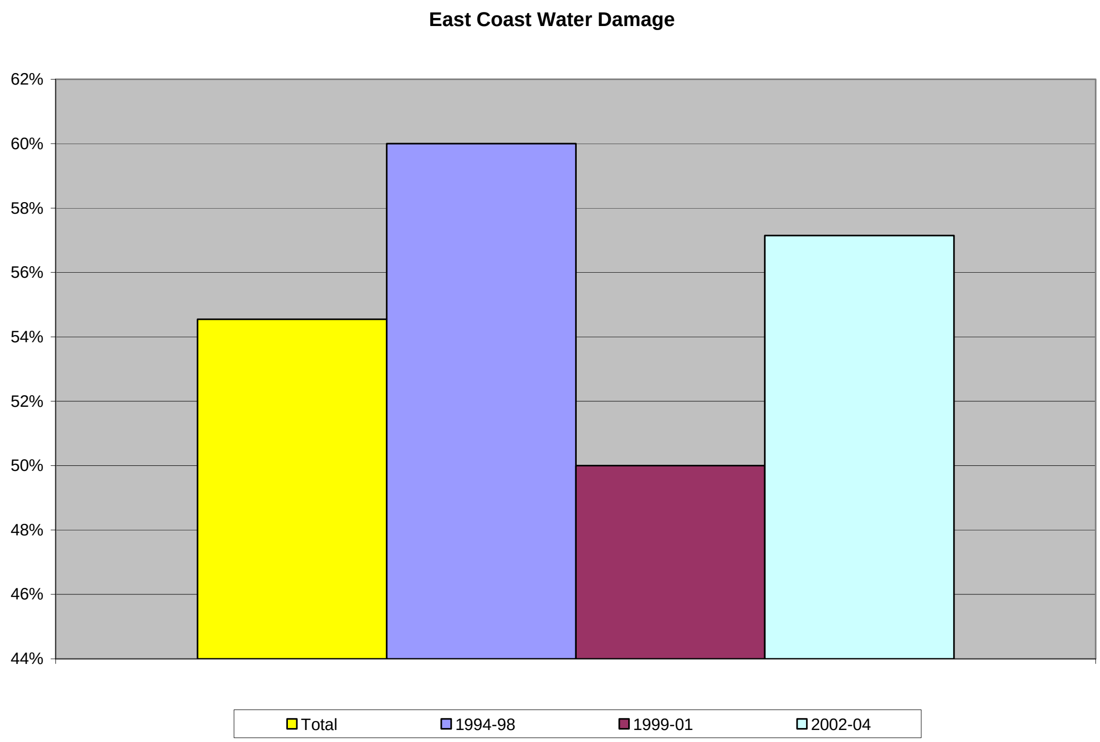

Figure 5: % of Homes with water penetration, Frances/Jeanne zone 8

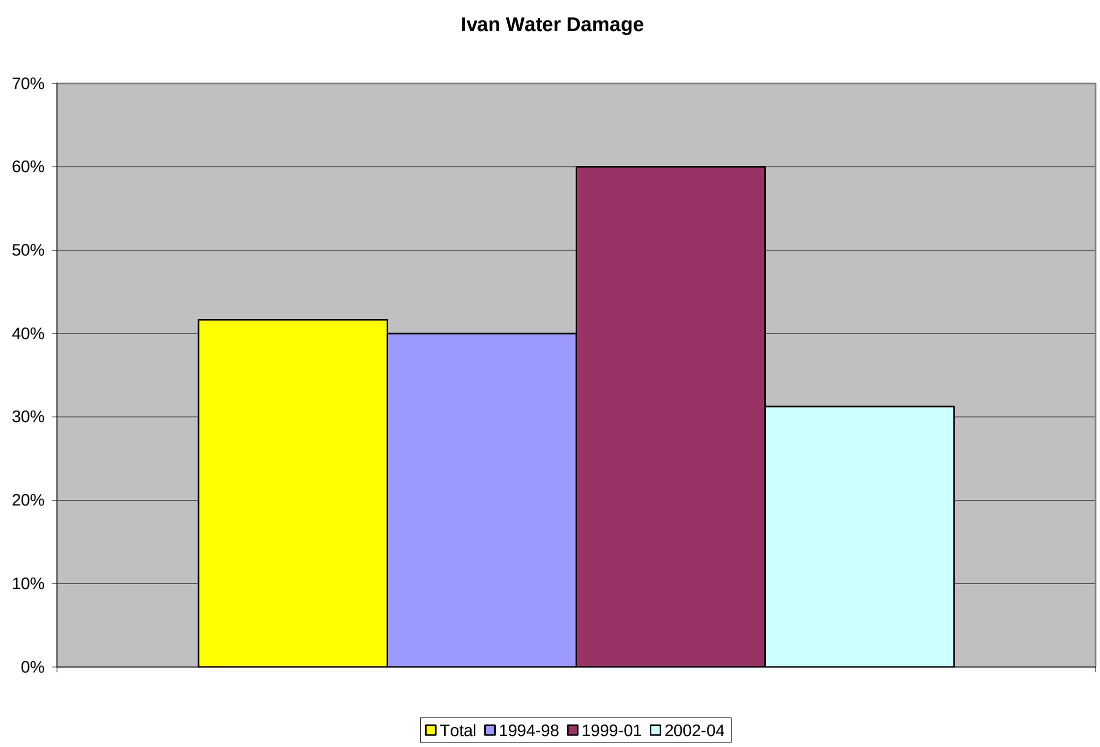

Figure 6: % of Homes with water penetration, Ivan zone 8

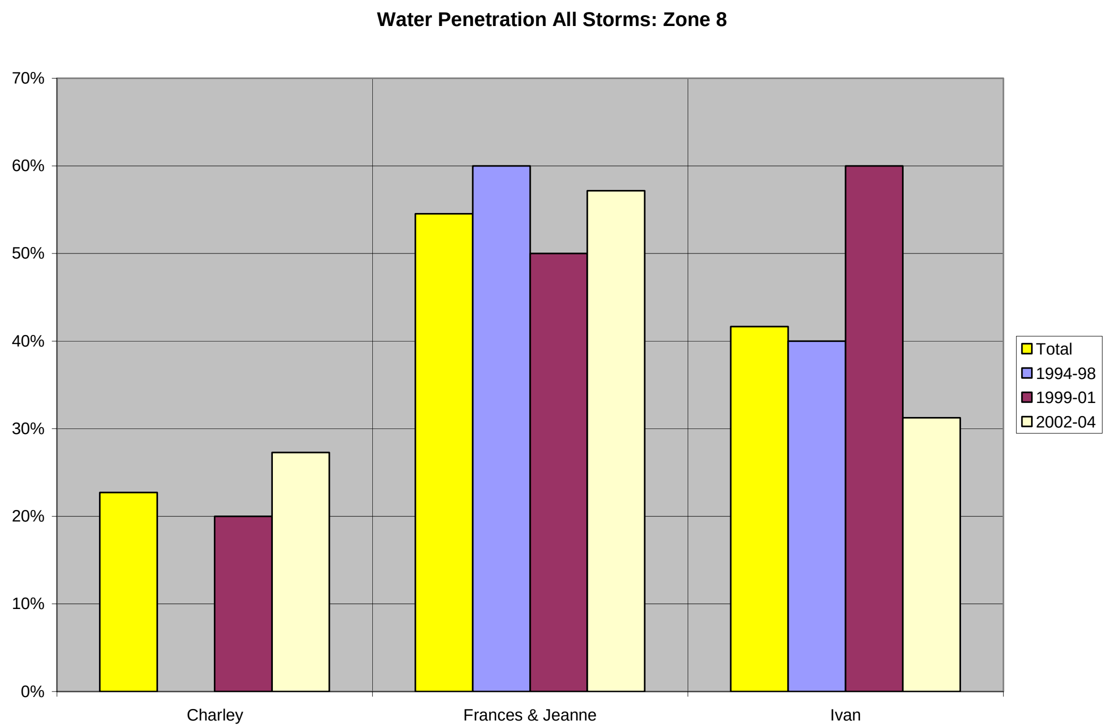

Figure 7: % of Homes with water penetration, all storms zone 8

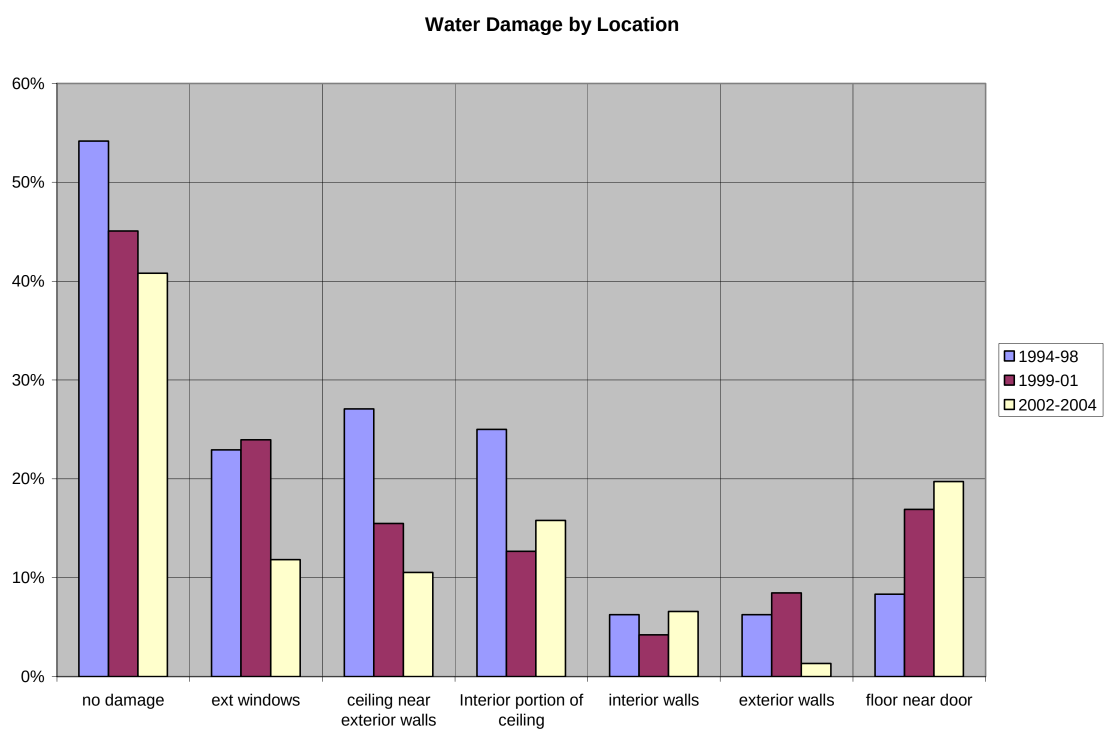

Figure 8: % water penetration by entry location, all storms all zones

Window Protection / Window Damage

Figures 9, 10 and 11 reveal the percentage of windows that were protected during the hurricane, where protection includes plywood, shutters, or impact resistance glass. Figure 9 is stratified by wind zone and building code and uses all data, Figure 10 is stratified by wind zone and building code for Charley data only, and Figure 11 is stratified by storm and building code.

Table 4 provides percentages of protection by type for both the 2004 season and homeowner intent for future seasons. It is encouraging to see that the no-protection category drops significantly from the 2004 season to the future intent of the homeowner. A follow up study may be warranted to determine the percentage of homeowners that followed through with their intent to purchase window protection.

Figures 12 and 13 present the percentage of surveyed windows that were damaged (scratched, cracked), breached, or permitted water penetration. Figure 12 presents this window damage information for all zone 8 (110 – 120 mph) data, and contrasts protected vs. unprotected windows as well as storms. Figure 13 presents this information for Charley data only, and compares relative damage for protected and unprotected windows by wind zone. Figure 12 shows that a small percent of unprotected windows were damages / breached in zone 8 winds, with an improved performance for protected windows. Figure 13 shows a significant percentage (3-4%) of unprotected windows were damaged in the highest wind zone 11 (140 – 150 mph) in Charley, while protected windows experienced significantly less damage. At the lower wind zone 8 (110 – 120 mph gust), Figure 12 shows that protected windows permitted almost no damage, while the % of unprotected windows was small but consistent among storms.

Figure 14 revisits the data used to present figures 12 and 13. In this case, the percentage of windows that were protected / damaged is replaced with the percentage of homes that suffered damage to at least one window. Protected vs. unprotected windows are delineated, as well as the predominant roof cover type in the neighborhood of the subject home. The vertical axis is the percentage of homes that suffered damage to at least one window. Relative to Figures 12 & 13, Figure 14 is a more dramatic presentation of the effectiveness of window protection (% of homes with window damage drops by 65%) and the need to emphasize improvements to the attachment of tile roof systems.

The upcoming sections on roof cover performance indicate that tile roof cover is more likely to fail than shingle roof cover in the highest wind zones (figures 24, 25, 29, 30). Thus at least a portion of the increase in window failure in tile neighborhoods can be attributed to a higher availability of roof cover wind borne debris. It is clear that tiles are a major concern for window vulnerability when wind speeds are high enough to cause significant loss of roof cover. Companion results for wind zone 8 (110 – 120 mph 3-sec gust) show a very low probability of window damage for both protected and unprotected windows at this wind speed range. This low probability of window damage was also observed for the zone 8 survey subjects in Ivan, Frances and Jeanne.

Figure 14 emphasizes that window openings are a critical breach point, with a significant percentage of homes (9.1% is the lowest value) requiring at least one window replacement in the highest 2 wind zones.

Table 4: Window protection use in 2004 and future storms

	% of homes in that region that used left column protection in 2004 (% that intend to use protection in future seasons)		
	Charley	Ivan	Frances / Jeanne
No protection	60 % (11%)	58% (33%)	16% (16%)
Plywood	7% (13%)	36% (36%)	13% (6%)
Shutters	27% (74%)	6% (27%)	53% (72%)
Impact Glass	7% (3%)	0% (3%)	19% (6%)

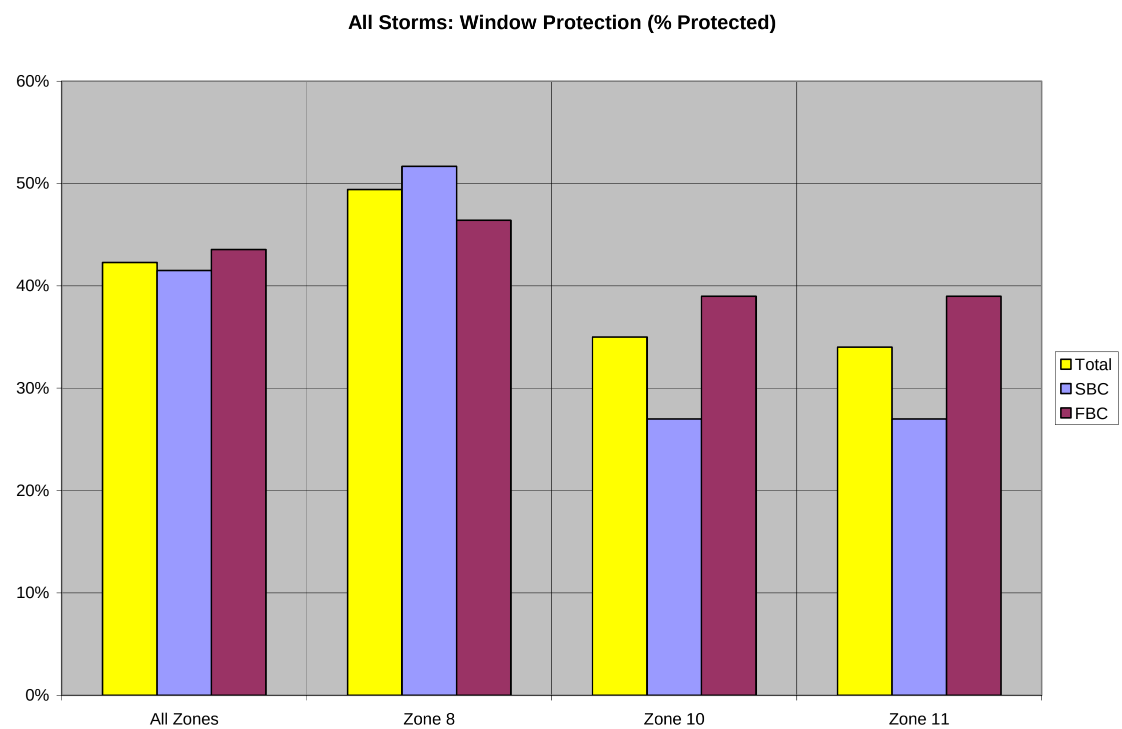

Figure 9: % of homes with window protection, all storms all wind zones

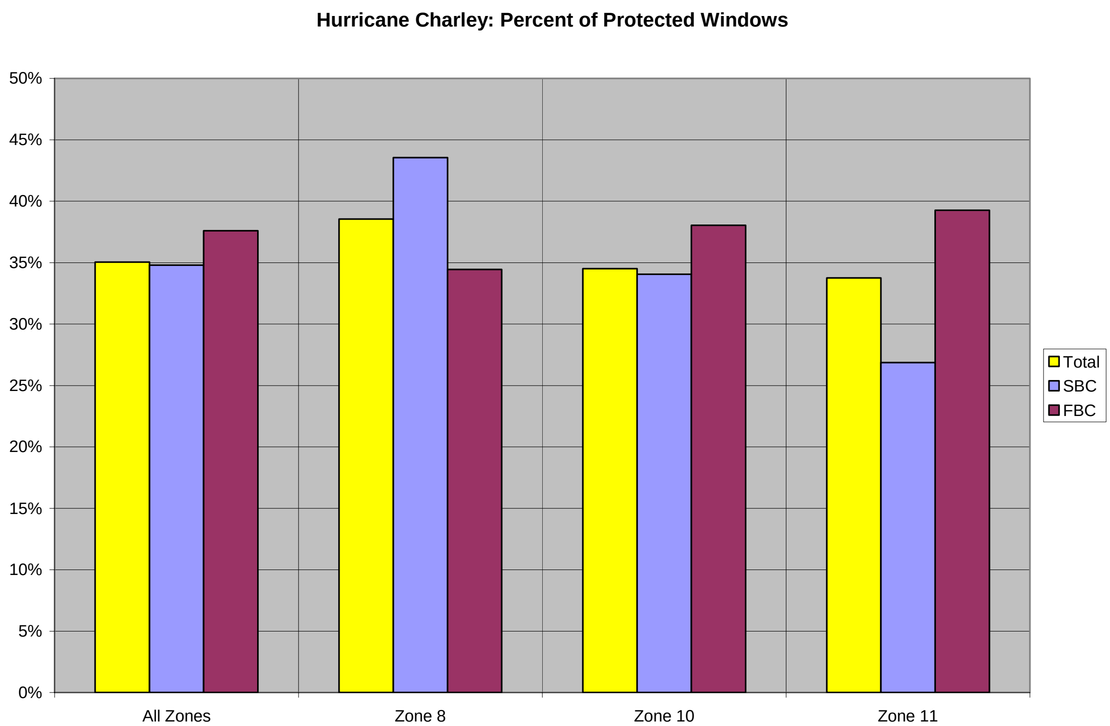

Figure 10:% of homes with window protection, Charley by wind zone

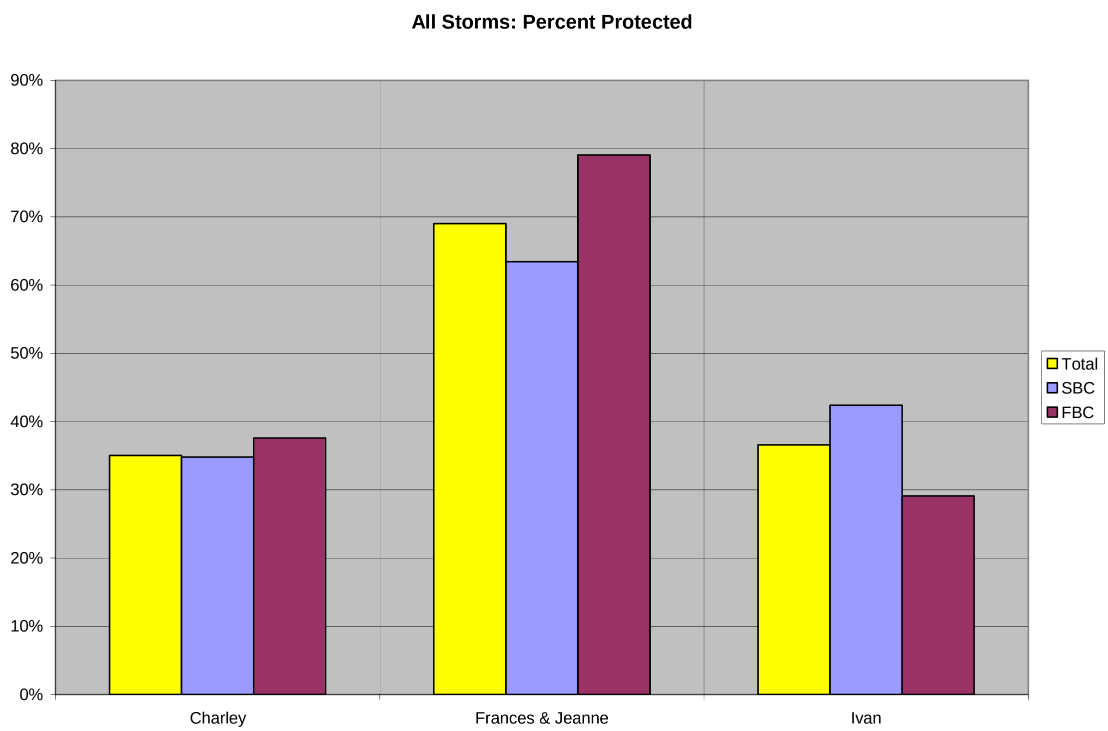

Figure 11:% of homes with window protection, by storm, all wind zones

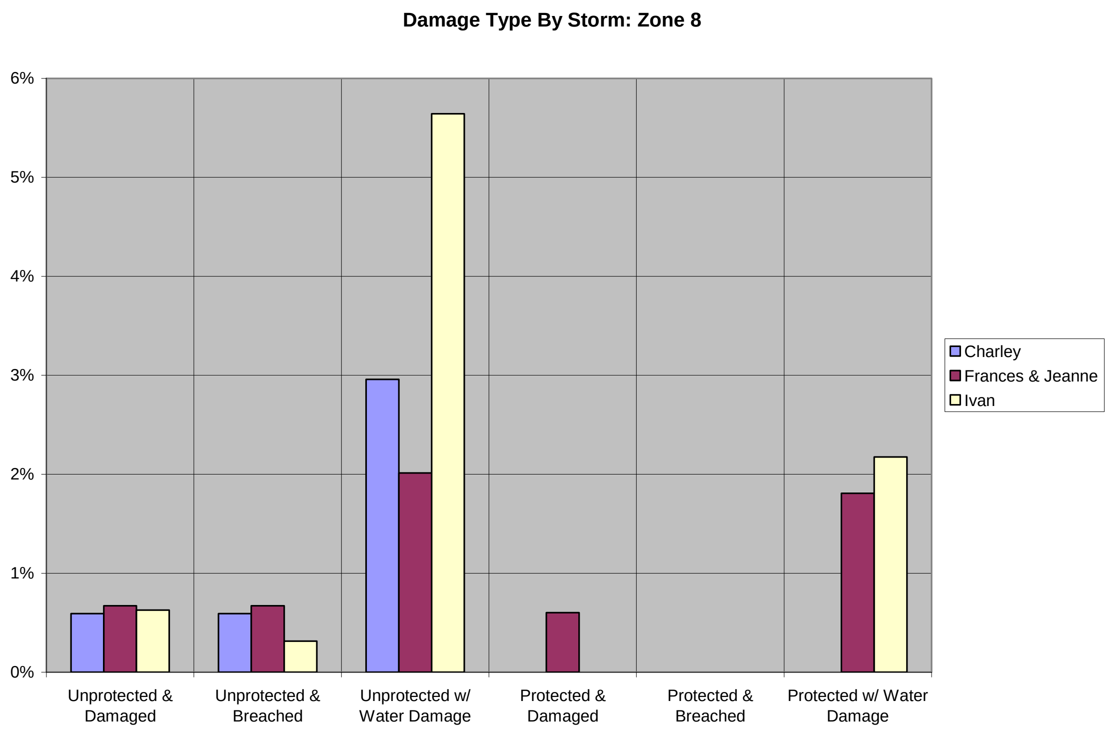

Figure 12: % of damaged and undamaged windows by protection and storm, zone 8

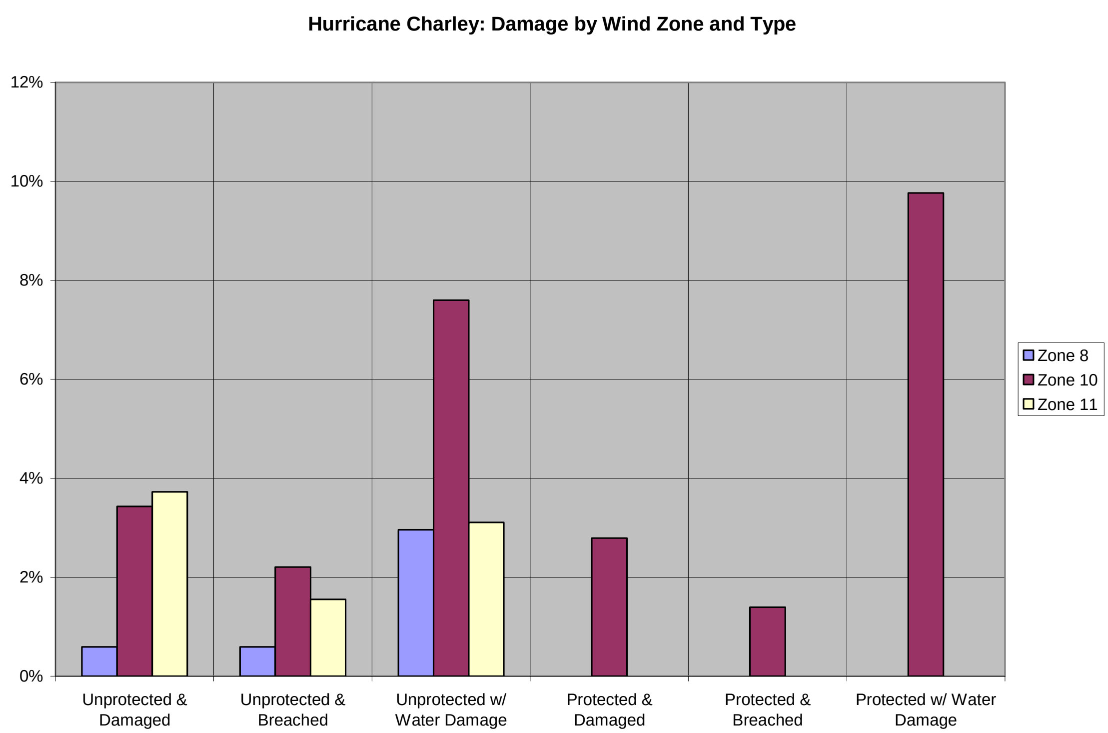

Figure 13: % of damaged and undamaged windows by protection and zone, Charley

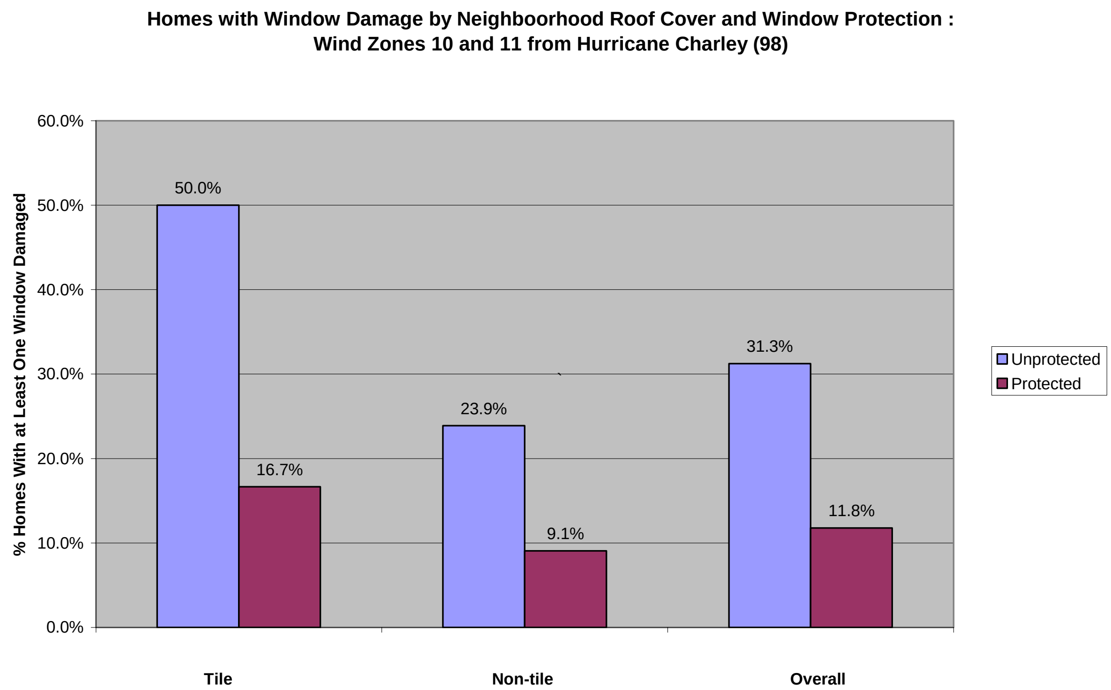

Figure 14: % of homes with at least one window damaged as a function of neighboring roof cover type and window protection. Data is from charley zones 10 & 11 combined

Soffit Damage

Figures 15 through 23 quantify the soffit damage from the surveys. Figures 15 - 17 show only the percentage of homes that experience any soffit damage (minor or major damage are not delineated). Figure 15 considers only the data from the 110 – 120 mph wind zone (zone 8) and compares the three Florida regions, stratified by three clusters of age of construction (1994 – 1998, 1999 – 2001, and 2002 – 2004). The Charley region has more houses with damage to the soffits, even in areas with wind speeds comparable to Frances, Jeanne and Ivan. Figure 16 combines all survey data (all wind speeds and regions) to provide a relative comparison of the likelihood of damage as a function of age.

Figure 18 shows both the likelihood of damage (blue line) as well as the average quantity of soffit damage to a given house (magenta line). A downward trend in likelihood of soffit damage can be seen from older to newer houses.

Figures 19 - 21 present the percentage of homes with no soffit damage, and the quantity of damage in 4 groups, stratified by age of construction. For comparison, 19 – 21 show Charley, Frances / Jeanne and Ivan in zone 8 winds (110 – 120 mph gusts). In all three figures, the vast majority of homes that did suffer soffit damage lost between 1 and 25% of the soffit.

Figure 22 presents this same information, now using the entire data set (all storms and wind zones). Figure 23 presents all wind zones only for Charley. In these figures a clear trend can be seen with increasing likelihood of soffit damage with increasing age of structure (only valid over the surveyed range 1994 – 2004). Only homes subjected to winds above 130 mph (Charley only) experienced damage to more than 50% of the soffit.

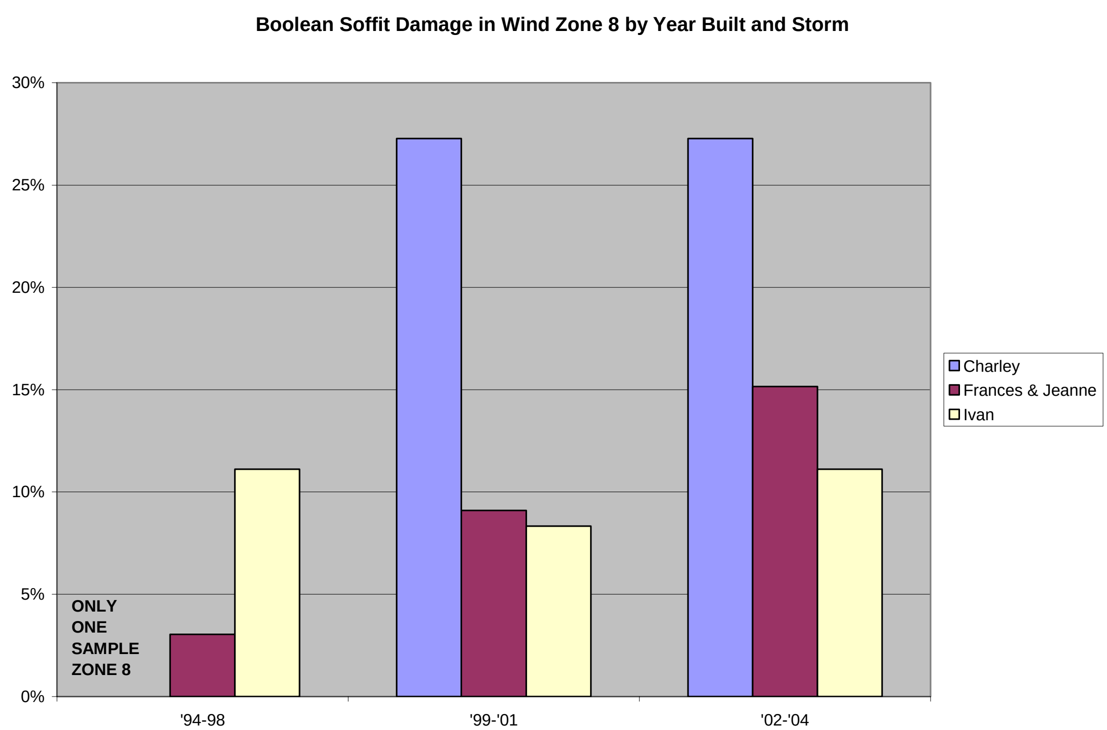

Figure 15: % of homes with soffit damage by age and storm, zone 8

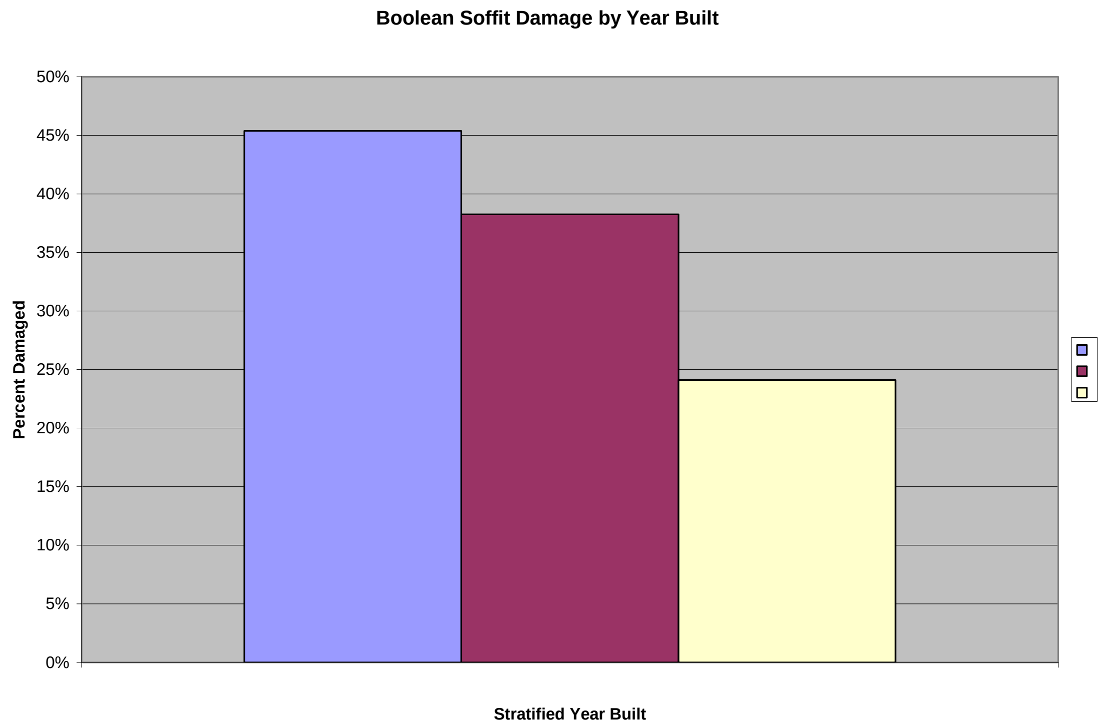

Figure 16: % of homes with soffit damage by age, all storms, all zones

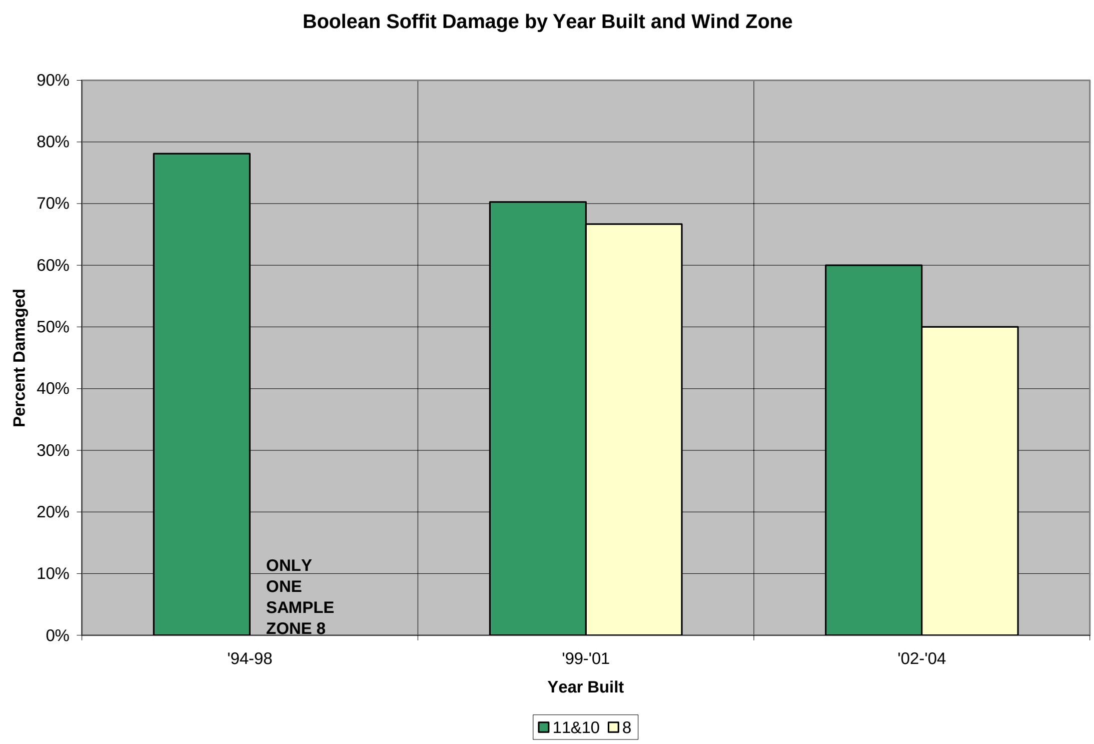

Figure 17: % of homes with soffit damage by age, all storms, all zones

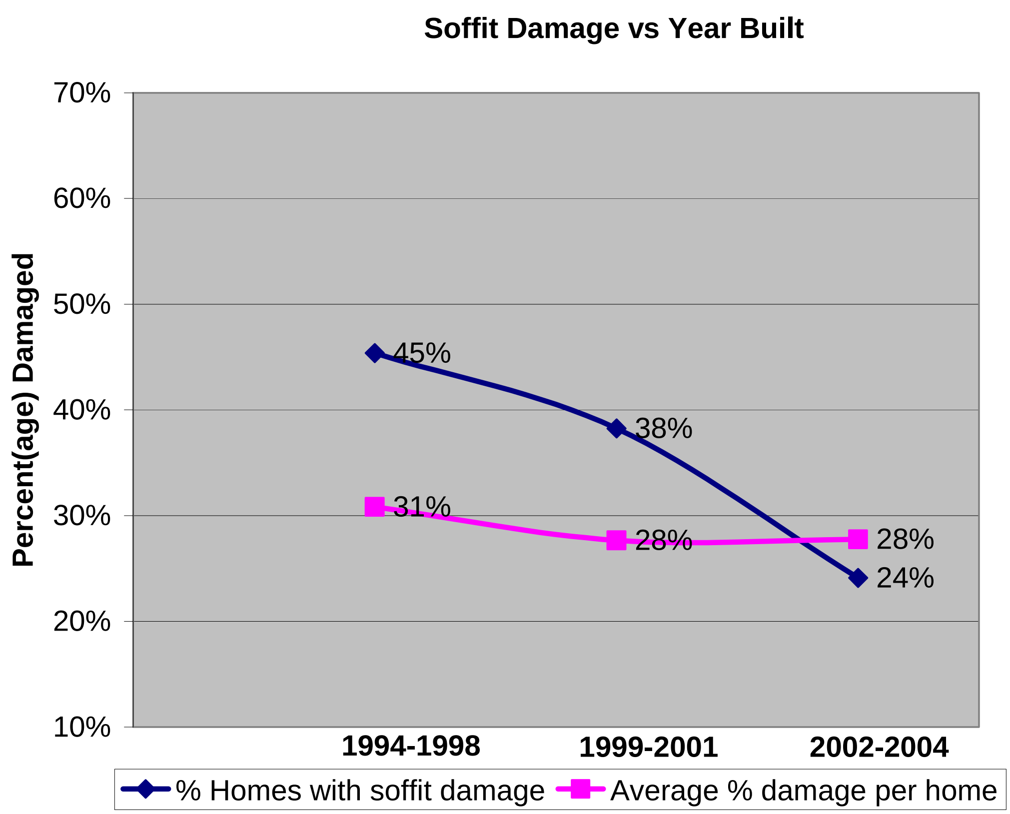

Figure 18: % of homes with soffit damage, and average % damage per home, Charley, all zones

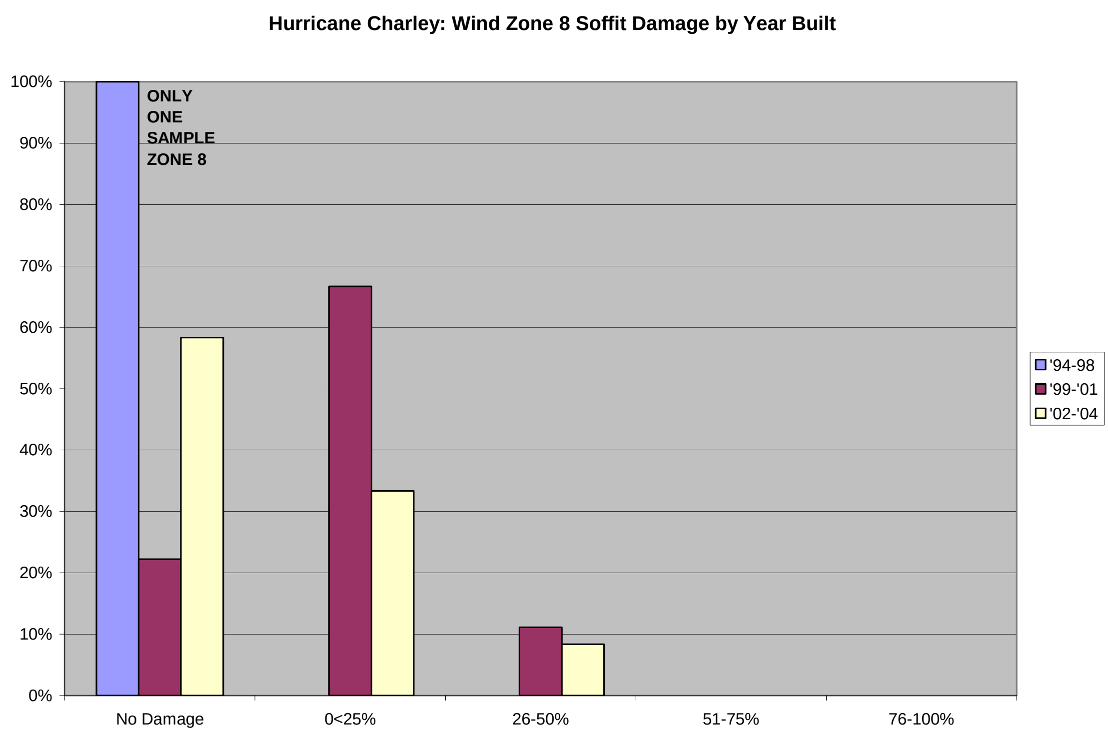

Figure 19: % of soffit damage, Charley, zone 8

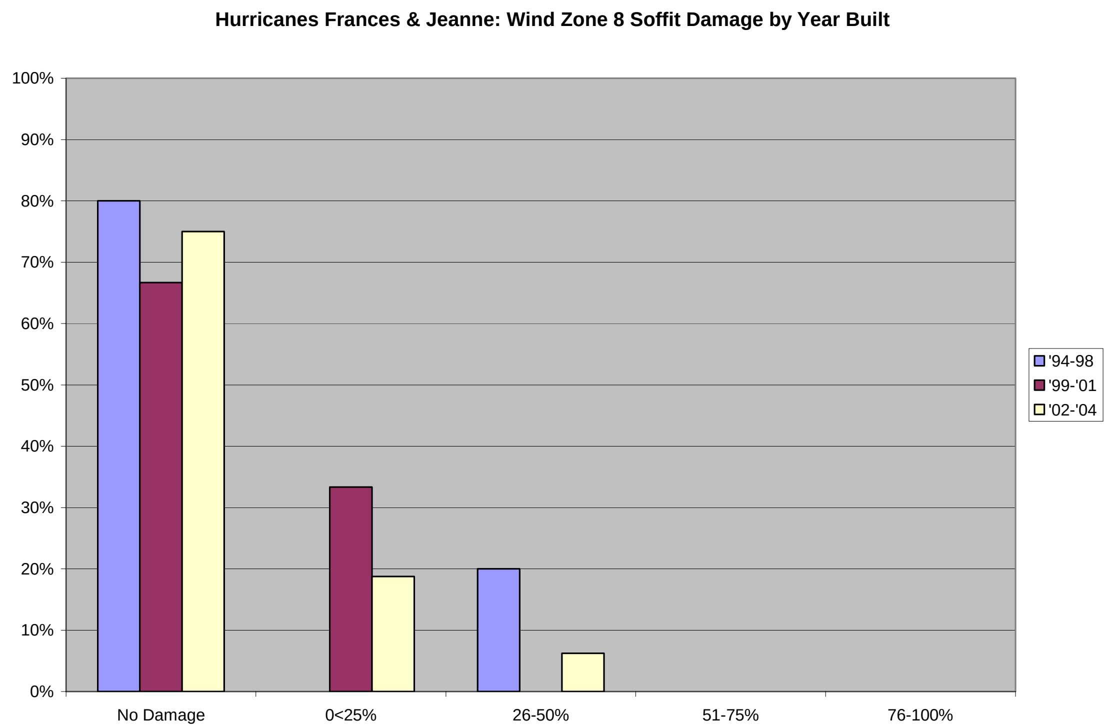

Figure 20: % of soffit damage, Frances & Jeanne, zone 8

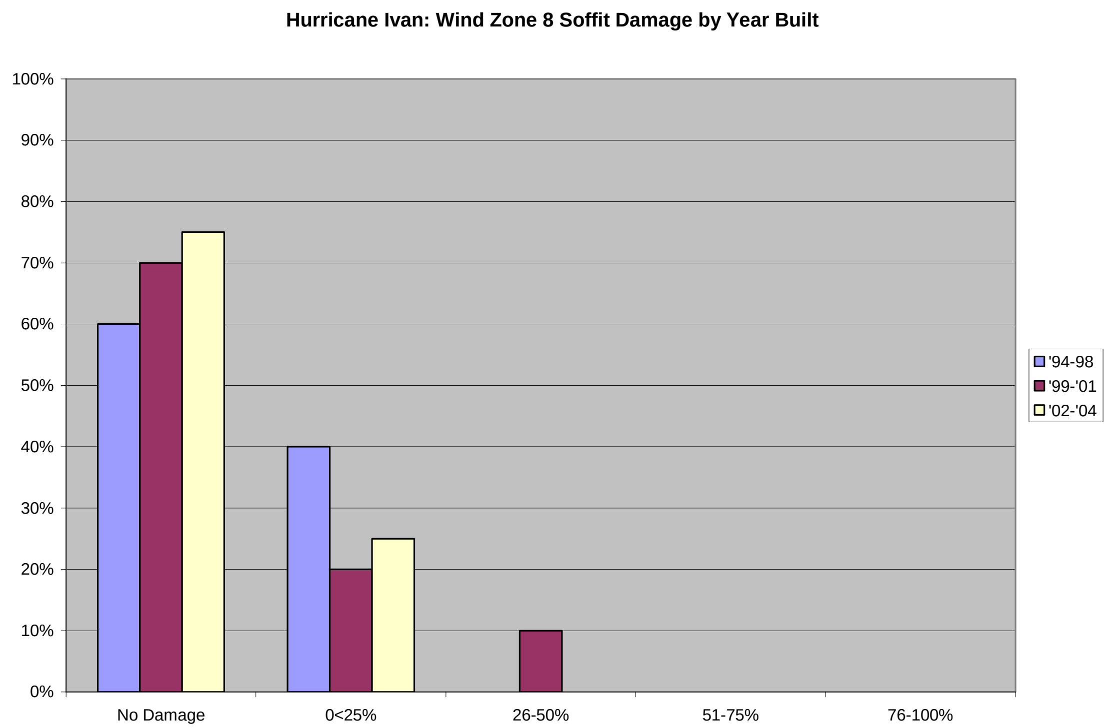

Figure 21: % of soffit damage, Ivan, zone 8

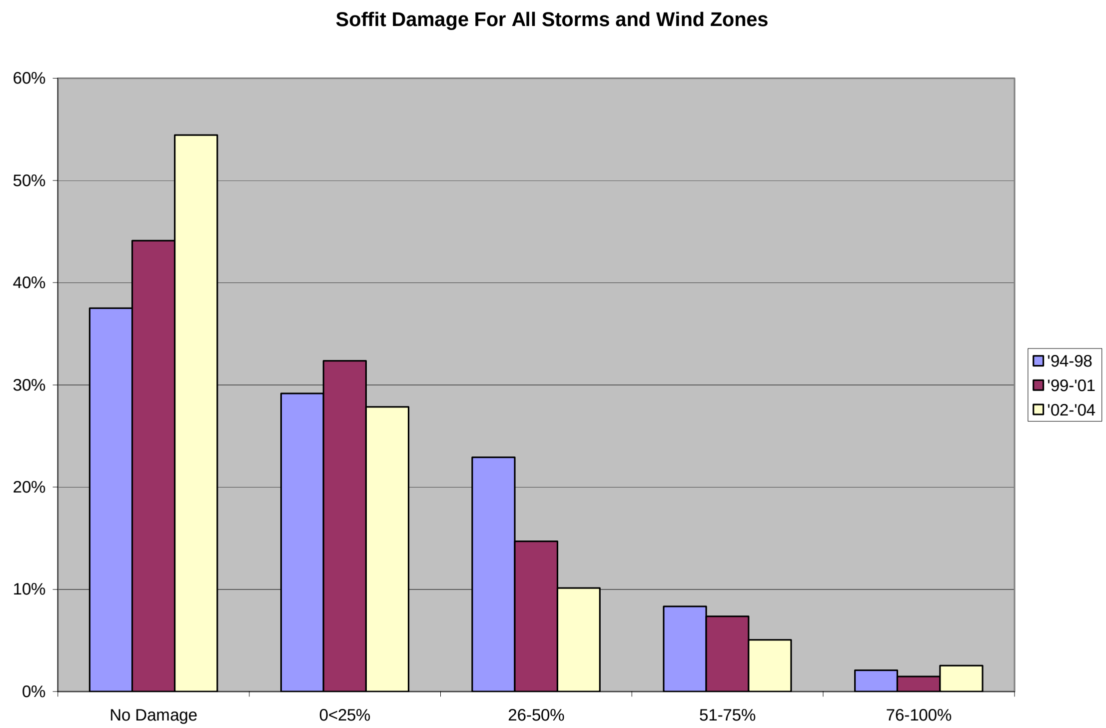

Figure 22: % of soffit damage, all storms, all zones

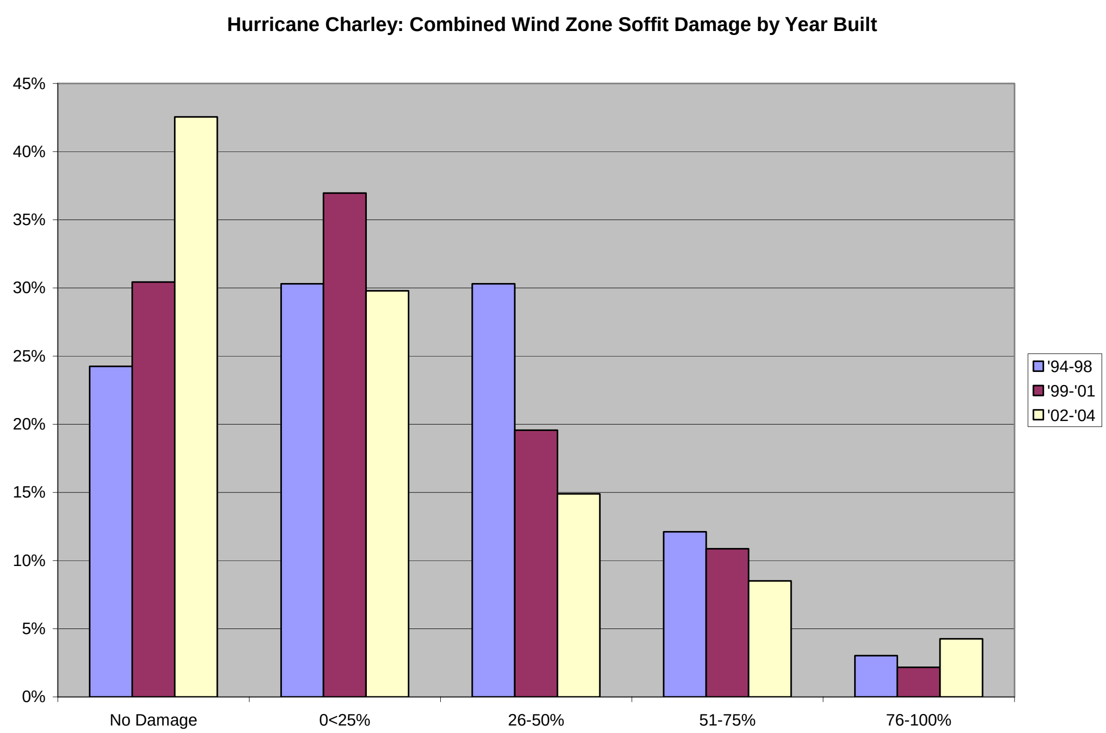

Figure 23: % of soffit damage, Charley, all zones

Roof Cover Damage

Figures 24 – 42 present roof cover loss data in several forms. Figures 24 – 27 present Boolean results, or the percentage of houses that had any roof damage regardless of the amount of damage, while Figures 28 – 42 quantify both the percentage of homes that had roof cover damage, and the amount of damage that occurred.

Figure 24 considers only Charley data, and stratifies results by wind zone and roof cover type (all, shingle only, and tile only). In general, the percentage of homes with roof cover damage increases with wind speed, with tile roofs performing badly at all speeds considered. Figure 25 presents this data in another format, with stratification by roof cover type, and the breakdown of the total roof damage by wind zone.

Figure 26 considers all surveyed homes with shingle roofs, offering a comparison of both wind zones in Charley, and regional difference from Charley to Frances / Jeanne to Ivan. Comparing performance of shingle roofs in the same wind swath (110 – 120 mph 3 second gust) in three regions, Charlotte County had significantly lower percentage of houses with shingle damage (32% of surveyed houses had damage) compared with St. Lucie County (80%) and Escambia County (50%). The increased shingle damage in St. Lucie County is due in some part to the passage of two storms. The effect of the storms individually cannot be delineated from this data set. In the Charley impacted region, as wind speeds increase from 120 mph to 140 and 150 mph peaks, the percentage of shingle homes that suffered roof cover loss rose from 32% to 65% to 79%.

Figure 27 is a continuation of Figure 26, where now the shingle damage is delineated by both region, zone, and age of construction. The trend in most stratifications is that older roofs faired worse than newer roofs.

Figures 28 – 31 consider all Charley data, presenting the percentage of homes with no roof cover loss, and the average amount of roof cover that is lost within ranges. Stratifications are in three age groups. Fig. 28 is for all roof cover types, Fig. 29 is for tile only, Fig. 30 is for shingle only, and Fig. 31 is for metal roofs.

Figures 32 & 33 consider only the Charley data in wind zone 8 (110 – 120 mph peak gust), and show results for all roof cover types, and just shingles, respectively. Figures 34 and 35 present these results for the Ivan and Frances / Jeanne regions for comparison with Charley in Figure 33. It is clear from Figures 33 – 35 that not only did a smaller percentage of homes suffer shingle damage in Charley, but those that did suffered far less damage on average (in comparable wind zones).

Figure 41 presents tile loss data for the highest Charley wind zone only stratified by 3 age groups (Figure 29 shows this data for all Charley wind zones combined). Very few surveyed tile roof homes of any age group had no cover damage. The quantity of damage did vary with age. Only 15% of 2002 – 2004 homes had tile damage exceeding 5%, indicating that the vast majority of new homes suffered only ridge cap loss (with only a few exceptions). Among the 1999 – 2001 group, 60% had over 5% damage, 22% over 10% damage, and 22% over 25% damage. Among the 1994 – 1998 group, 60% of the samples had damage quantity in the range of 6-25%. Overall this indicates a much higher probability of field tile loss in homes built 1994 – 2001 compared to new construction.

Figures 37 – 39 consider Charley data from wind zone 10 (130 – 140 mph), presenting percentage of roof cover loss overall, for tiles, and for shingles respectively. Figures 40 – 42 present this same information for Charley surveys in wind zone 11 (140 – 150 mph). Figure 42 clearly shows a distinct difference in shingle performance by age at the highest wind speed, with significant quantities of shingle damage to the age group 1994 – 1998, less damage in 1999 – 2001, and even less in the FBC group 2002 – 2004. Figure 41 shows similar but far less pronounced behavior for tile roofs.

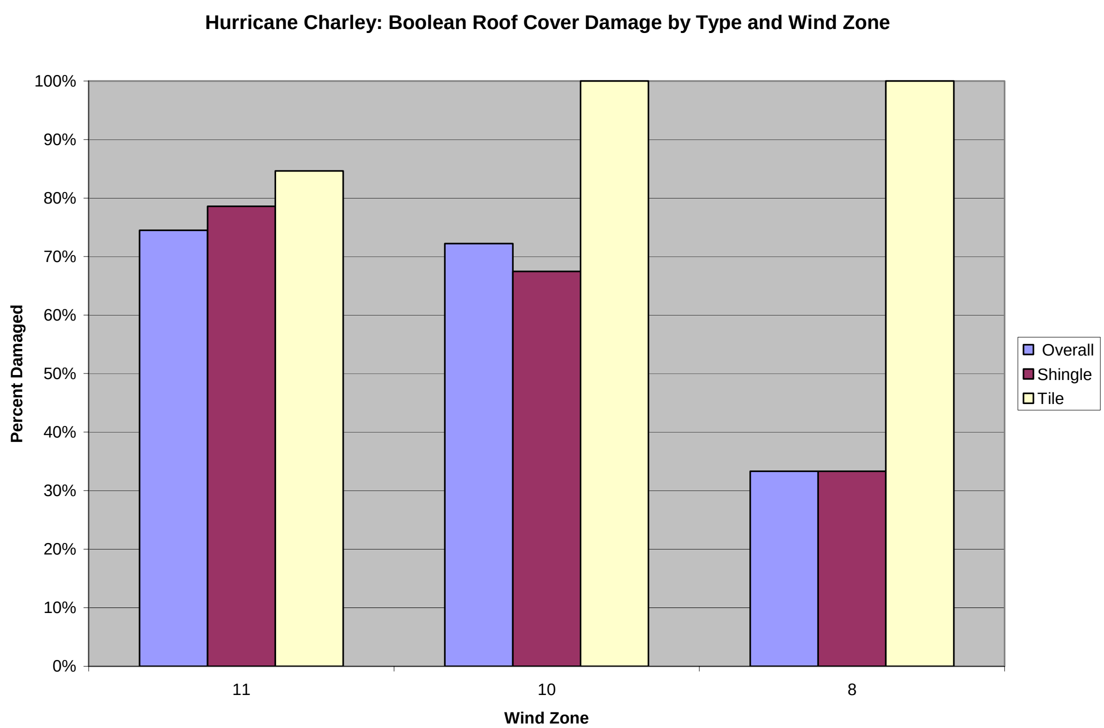

Figure 24: % of homes with roof cover damage by type, Charley, all zones

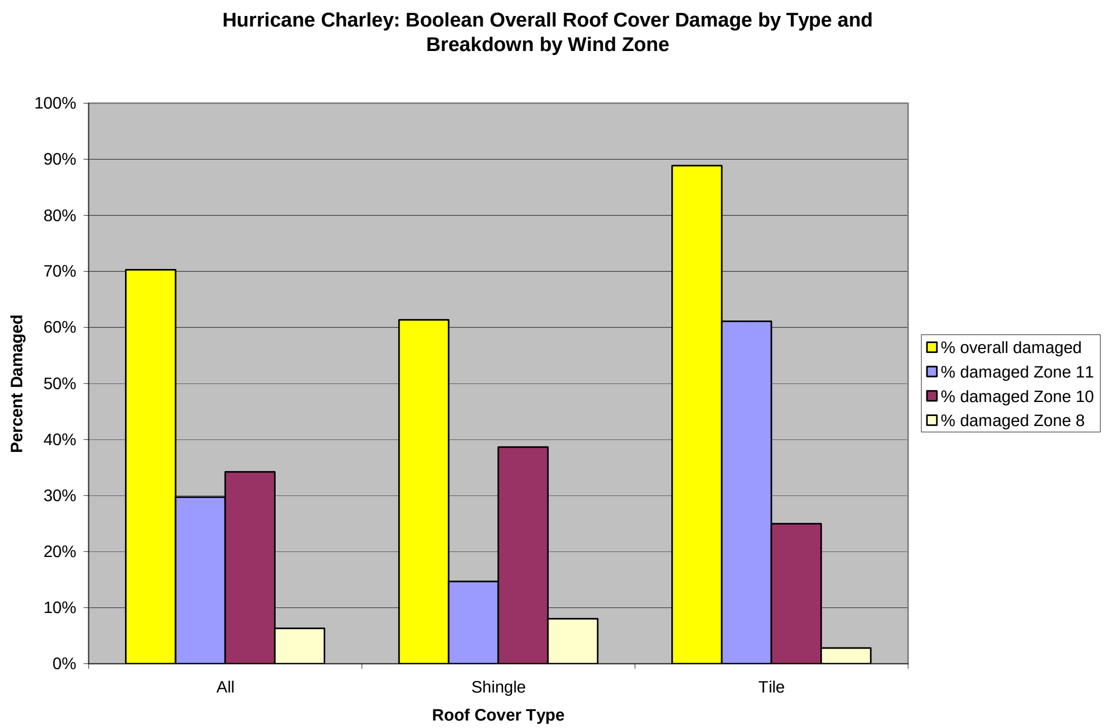

Figure 25: % of homes with roof cover damage by type, Charley, all zones

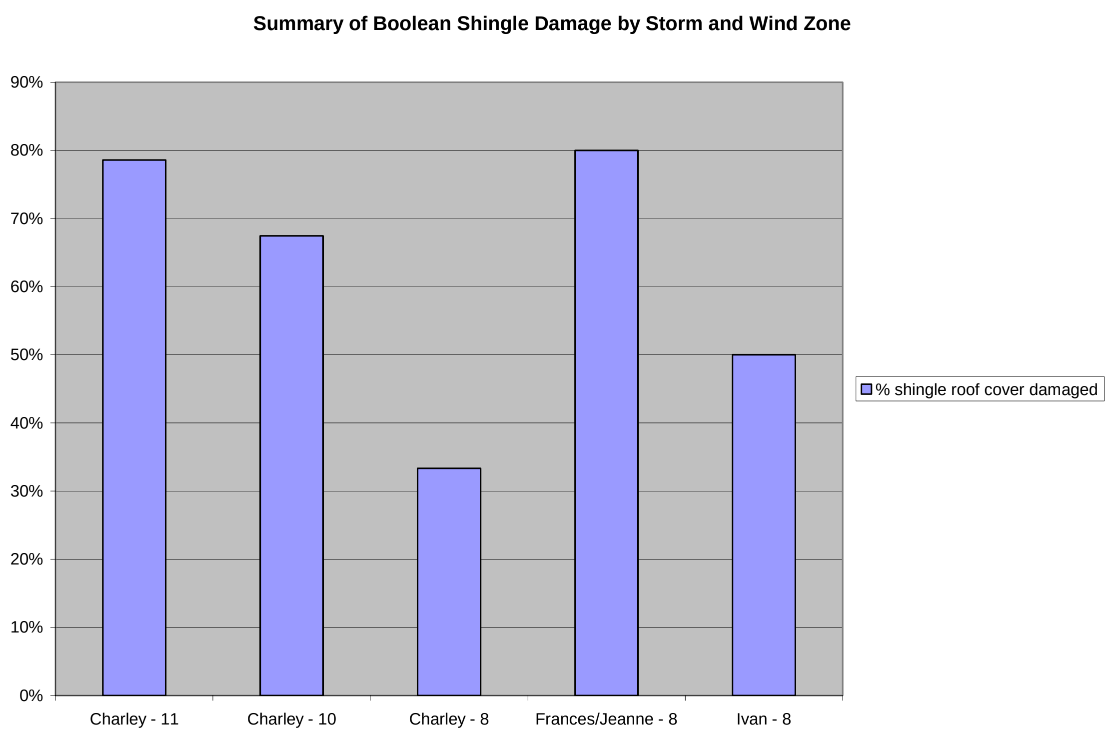

Figure 26: % of homes with shingle damage, by storm, by zone

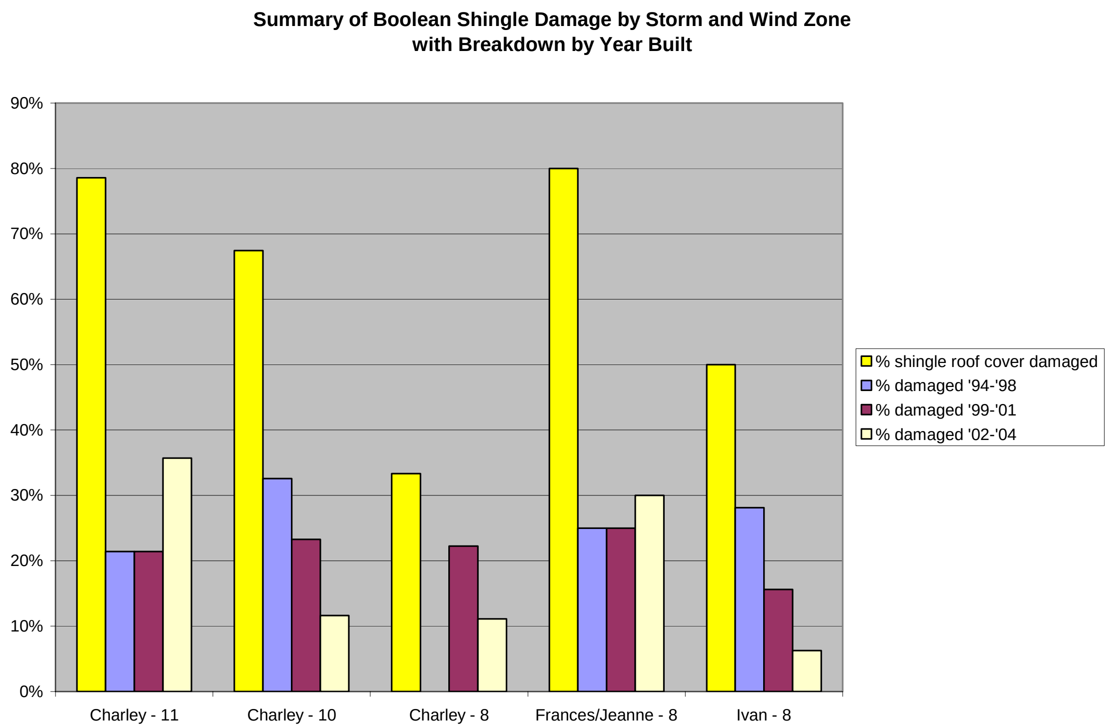

Figure 27: % of homes with shingle damage, by storm, by zone, by age

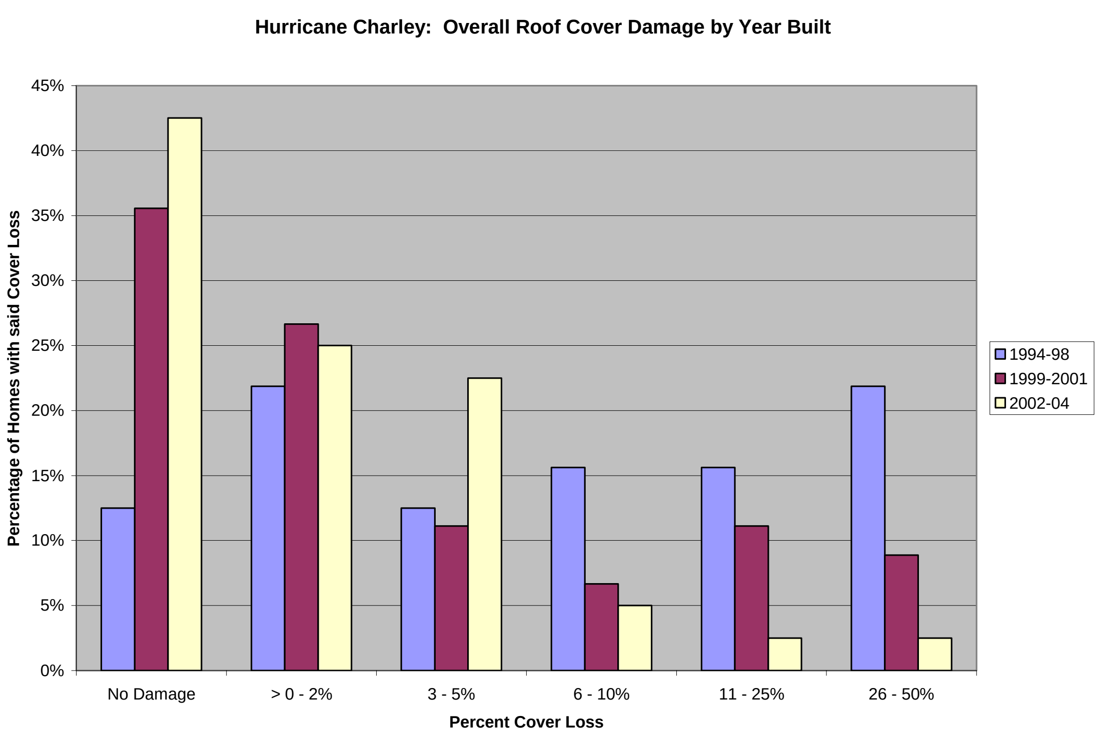

Figure 28: % of roof cover damage by age, Charley, all zones

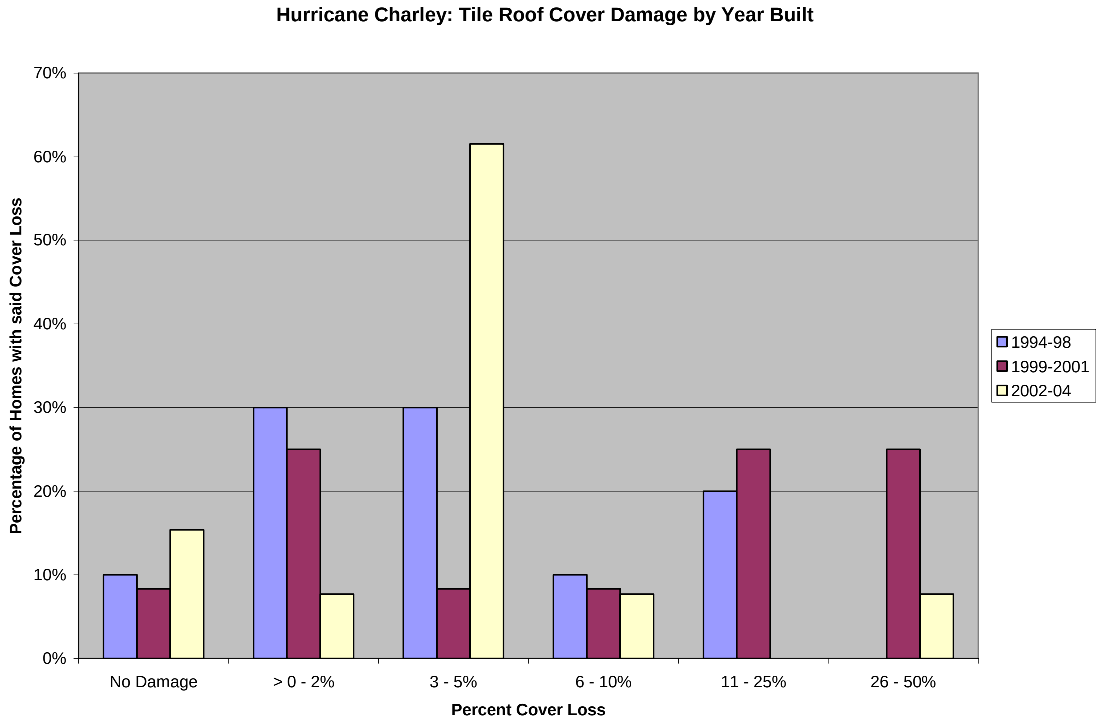

Figure 29: % of tile roof cover damage by age, Charley, all zones

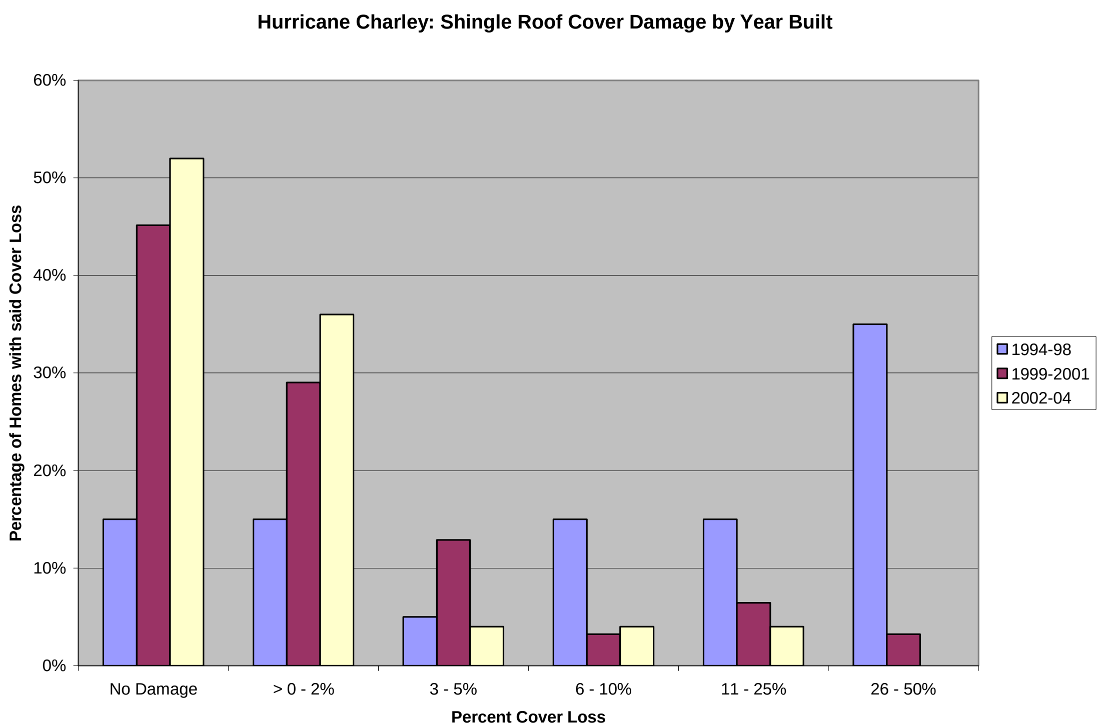

Figure 30: % of shingle roof cover damage by age, Charley, all zones

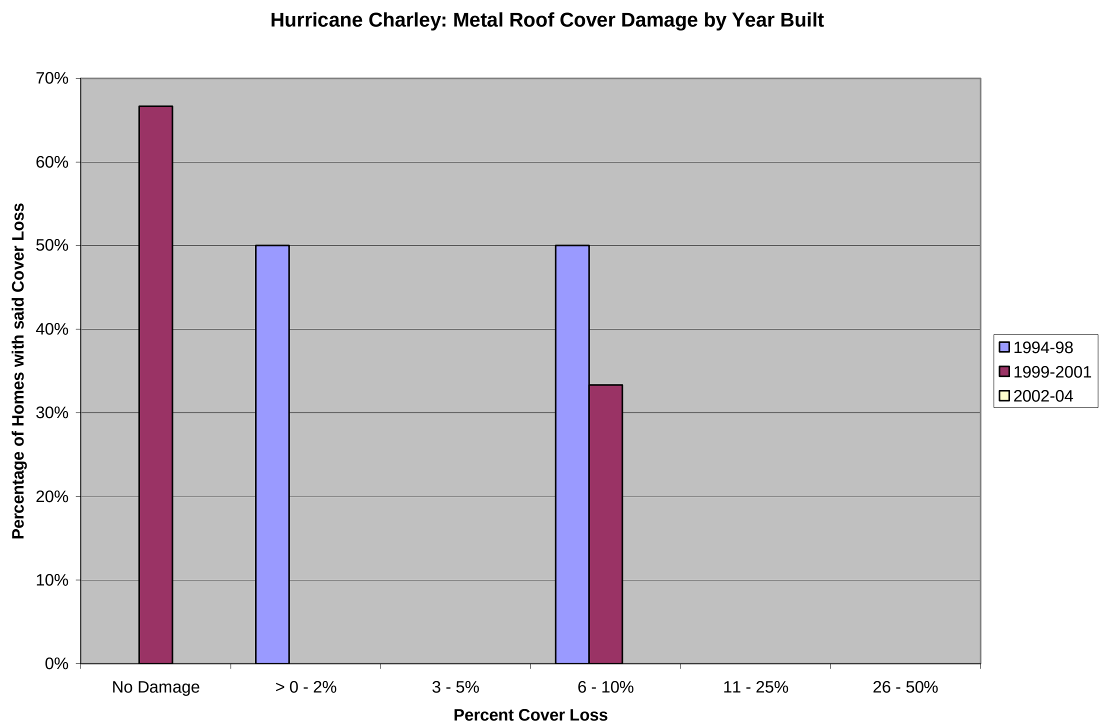

Figure 31: % of metal roof cover damage by age, Charley, all zones

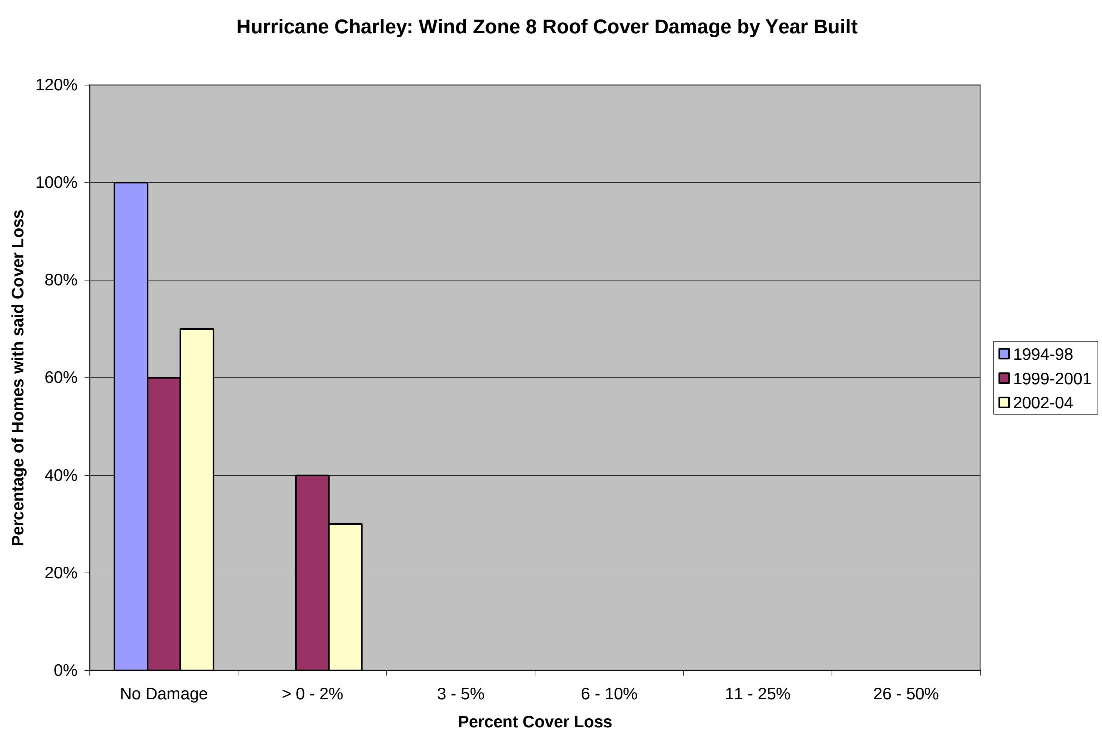

Figure 32: % of roof cover damage by age, Charley, zone 8

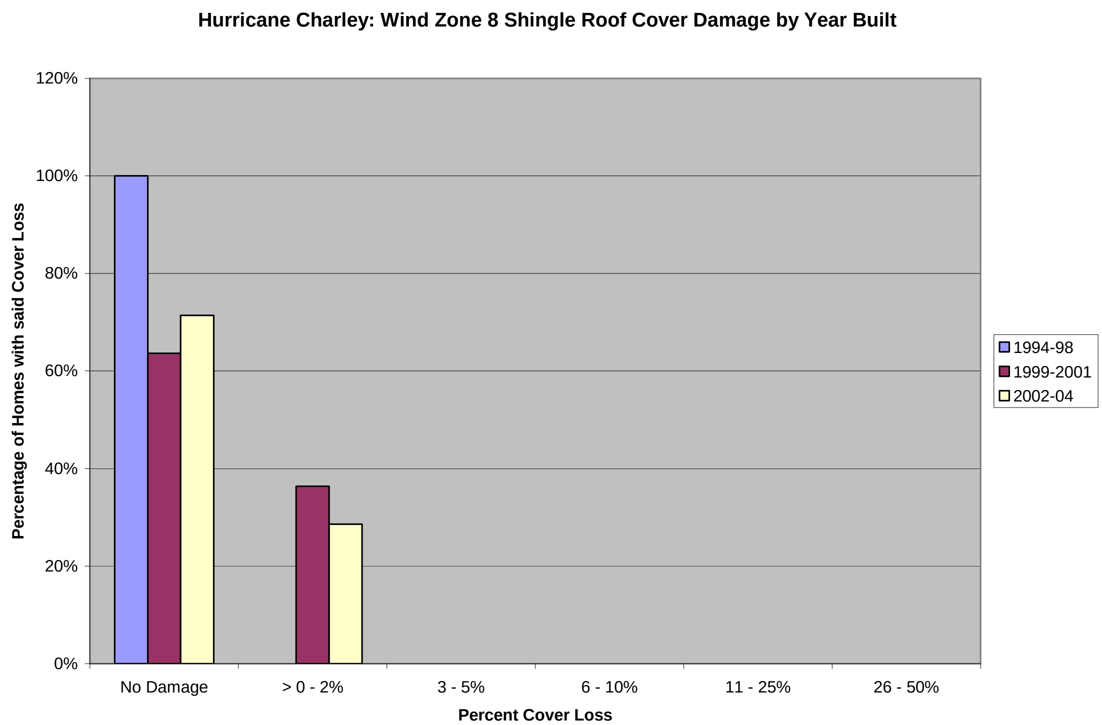

Figure 33: % of shingle roof cover damage by age, Charley, zone 8

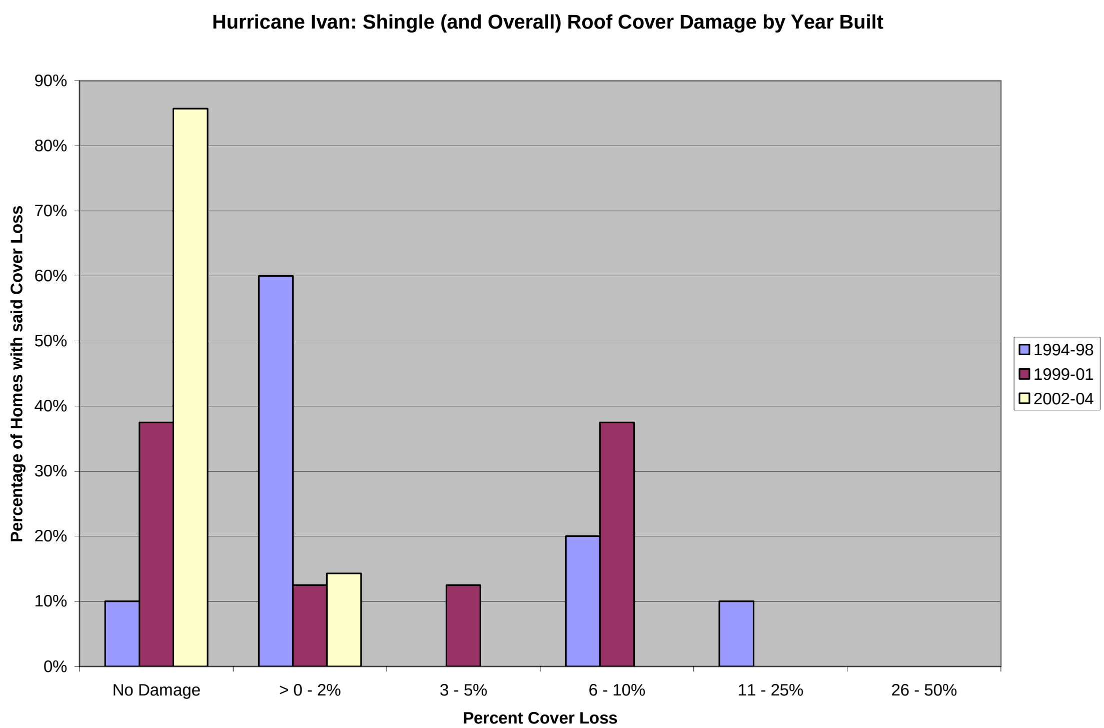

Figure 34: % of shingle roof cover damage by age, Ivan, zone 8

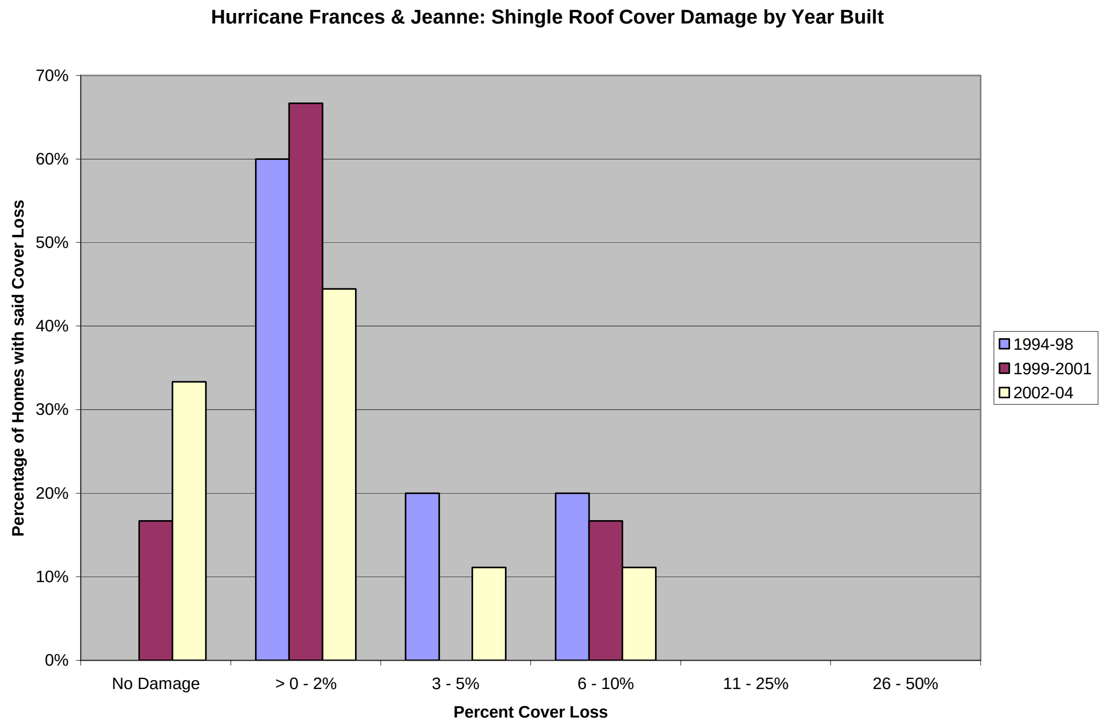

Figure 35: % of shingle roof cover damage by age, Frances & Jeanne, zone 8

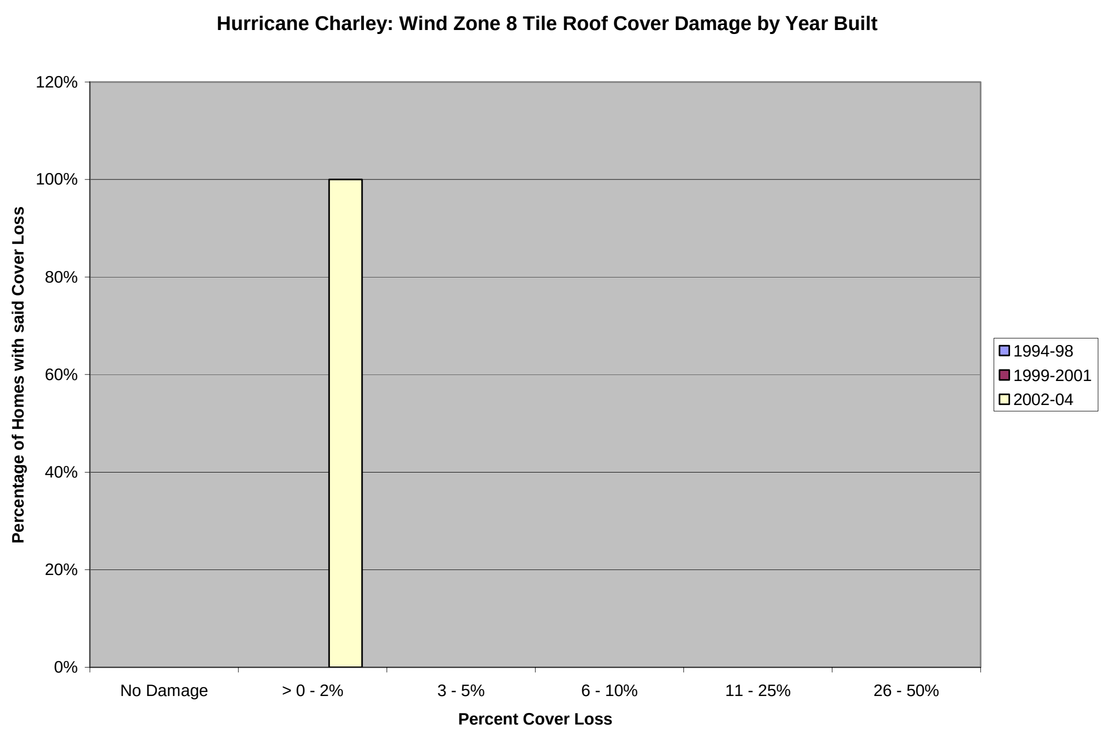

Figure 36: % of tile roof cover damage by age, Charley, zone 8

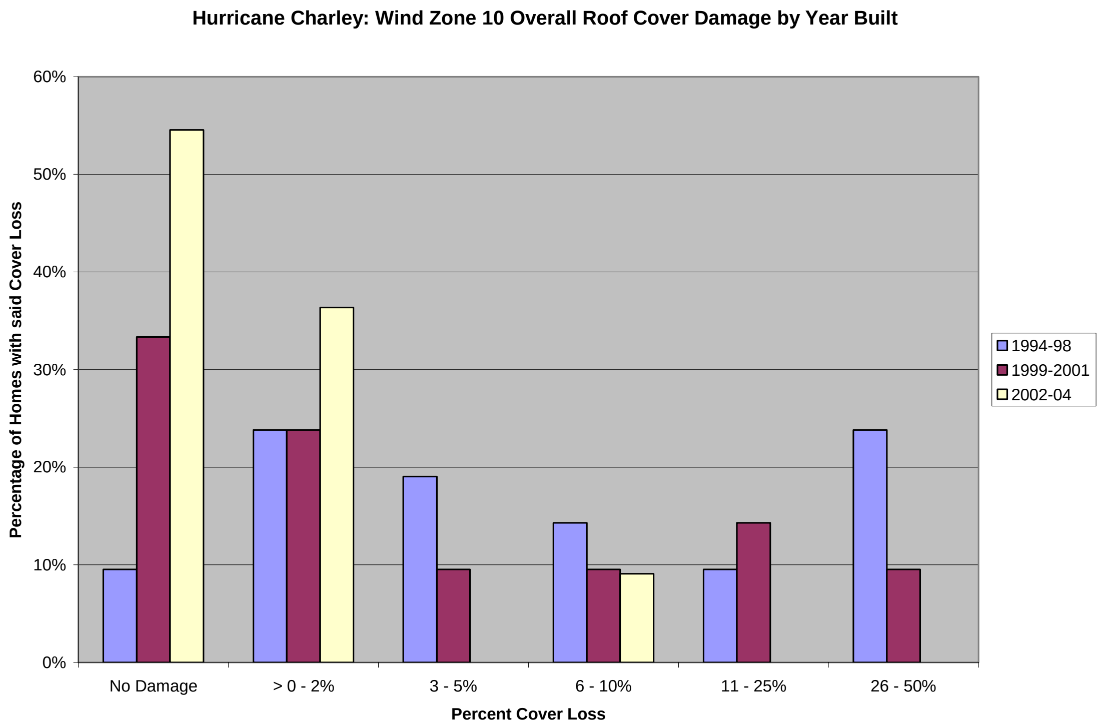

Figure 37: % of roof cover damage by age, Charley, zone 10

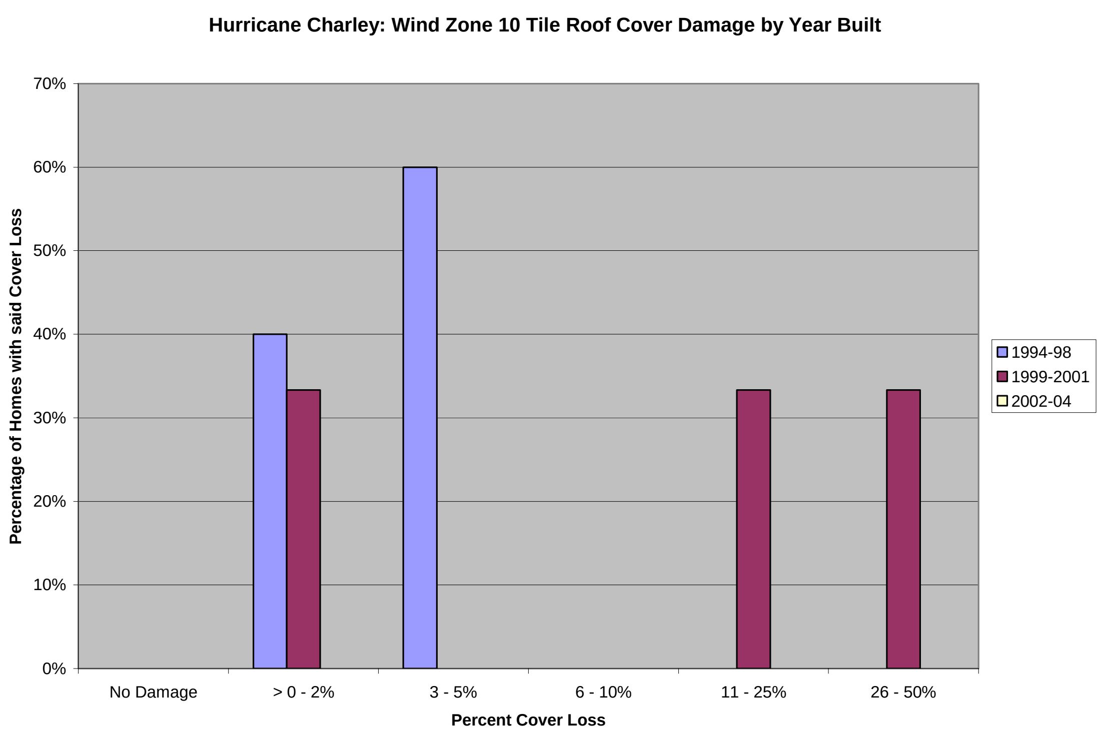

Figure 38: % of tile roof cover damage by age, Charley, zone 10

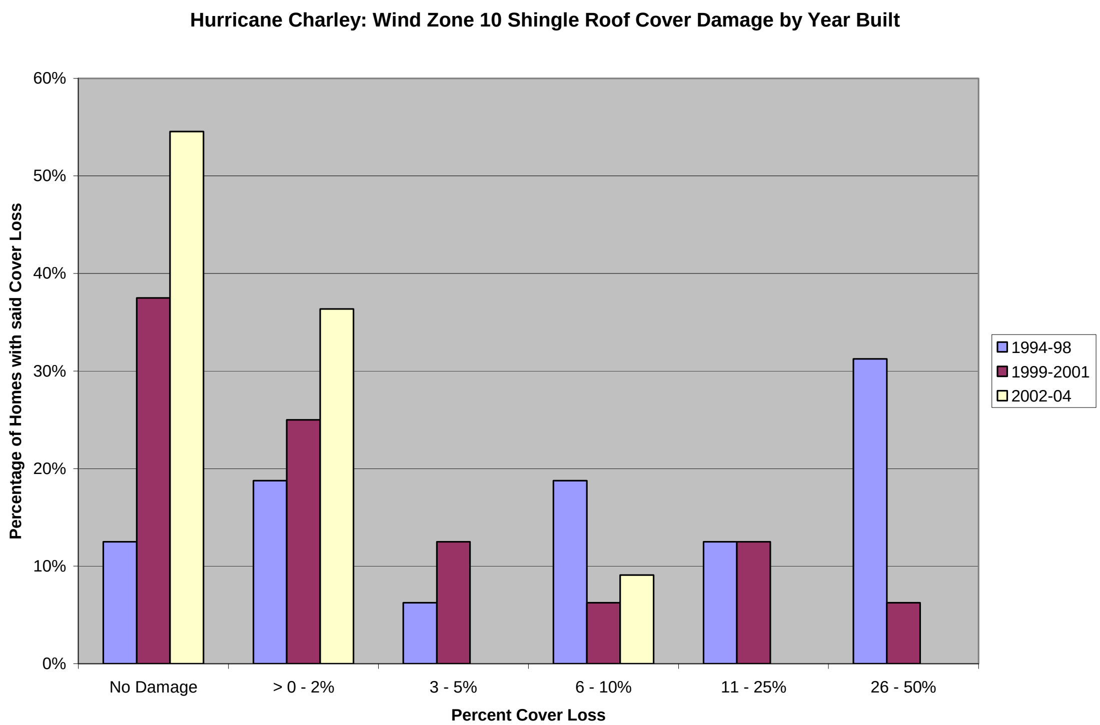

Figure 39: % of shingle roof cover damage by age, Charley, zone 10

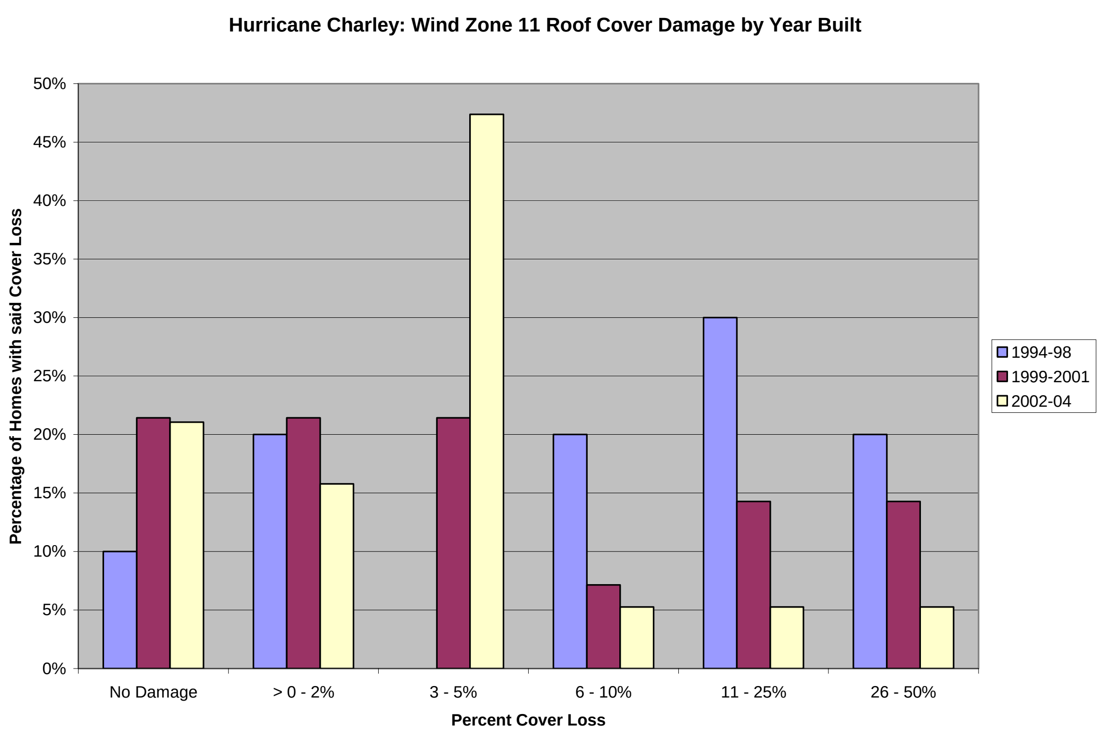

Figure 40: % of roof cover damage by age, Charley, zone 11

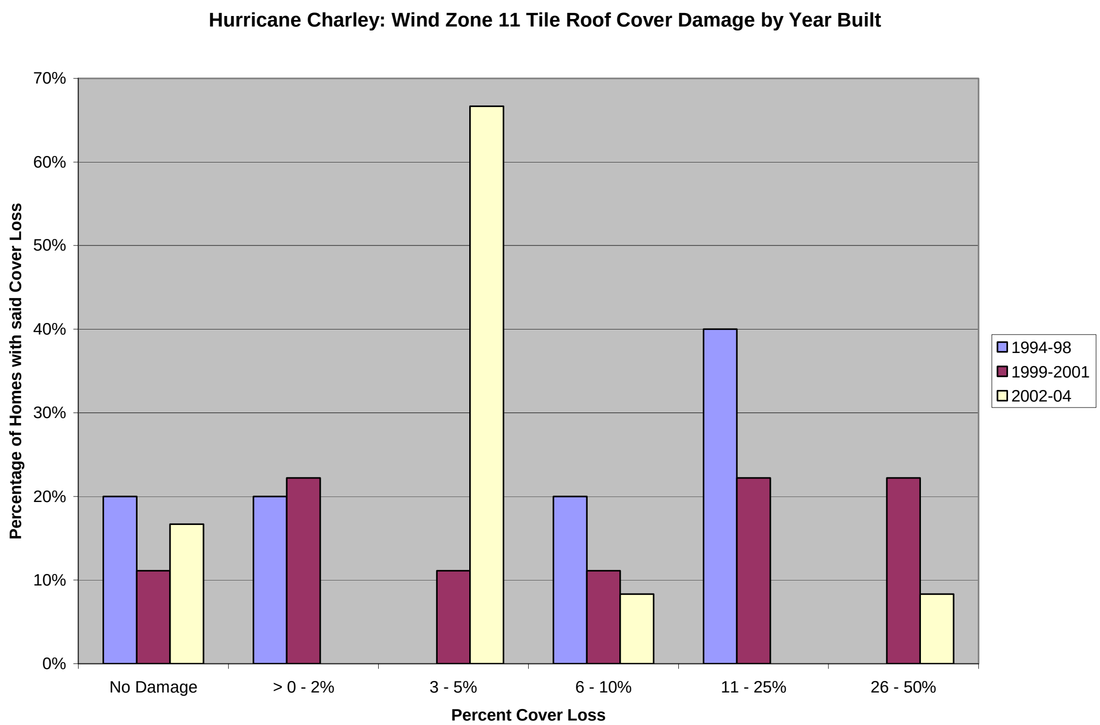

Figure 41: % of tile roof cover damage by age, Charley, zone 11

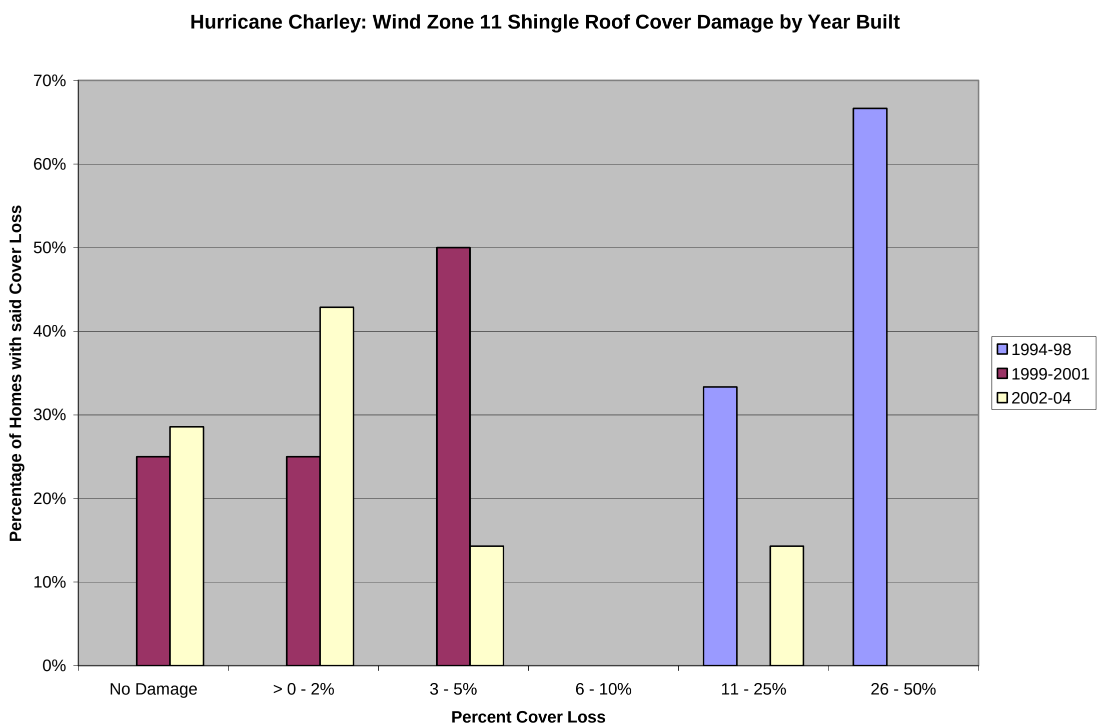

Figure 42: % of shingle roof cover damage by age, Charley, zone 11

Attic / Roof Attributes

Data collected in the surveys includes rood and attic attributes including frequency of roof to wall connections, sheathing type and thickness, and sheathing nail size and field spacing. This information in presented in Figures 43 – 54.

Figure 43 shows the roof to wall connection frequency stratified by region and year of construction as a percentage of those surveyed homes that had a connection in place at every truss. Charlotte County showed the highest compliance of a connection at every truss with 95%, while St. Lucie and Escambia Counties dropping to 92% and 83%, respectively. The oldest construction age group (1994 – 1998) consistently has the lowest compliance with St. Lucie County the lowest rate at 65%.

Figure 44 shows the breakdown of plywood to OSB sheathing, with percentage of OSB at 22%, 26%, and 85% for Charlotte, St. Lucie and Escambia Counties, respectively. None of the surveyed homes suffered sheathing loss due to uplift. A small handful of homes in Escambia County had roof sheathing loss due to tree damage.

Figures 45 – 48 show a more detailed breakdown of sheathing attributes, including thickness by age group for OSB and plywood separately for the total sample set, Charlotte County, St. Lucie County and Escambia County respectively.

Figures 49 – 51 show the sheathing fastener type stratified by age group for Charlotte, St. Lucie and Escambia Counties, respectively. There is an increasing conformity to 8d nails with more recent construction, and a small percentage of staples in the oldest group for the Charley and Ivan regions.

Figures 52 – 54 present sheathing fastener field spacing stratified by age group for Charlotte, St. Lucie and Escambia Counties, respectively. All three regions show increasing conformity to six inch field spacing with newer construction. Charlotte County shows a significant percentage of FBC construction with spacing closer than six inches. Only a few cases of FBC construction had spacing greater than six inches. 33% of the homes built between 1994 and 1998 had a field spacing of 10 inches in St. Lucie County, and 75% of that age group had eight inch spacing in Escambia County. Charlotte County had the largest percentage of field spacing at six inches or less over all age groups sampled (1994 – 2004).

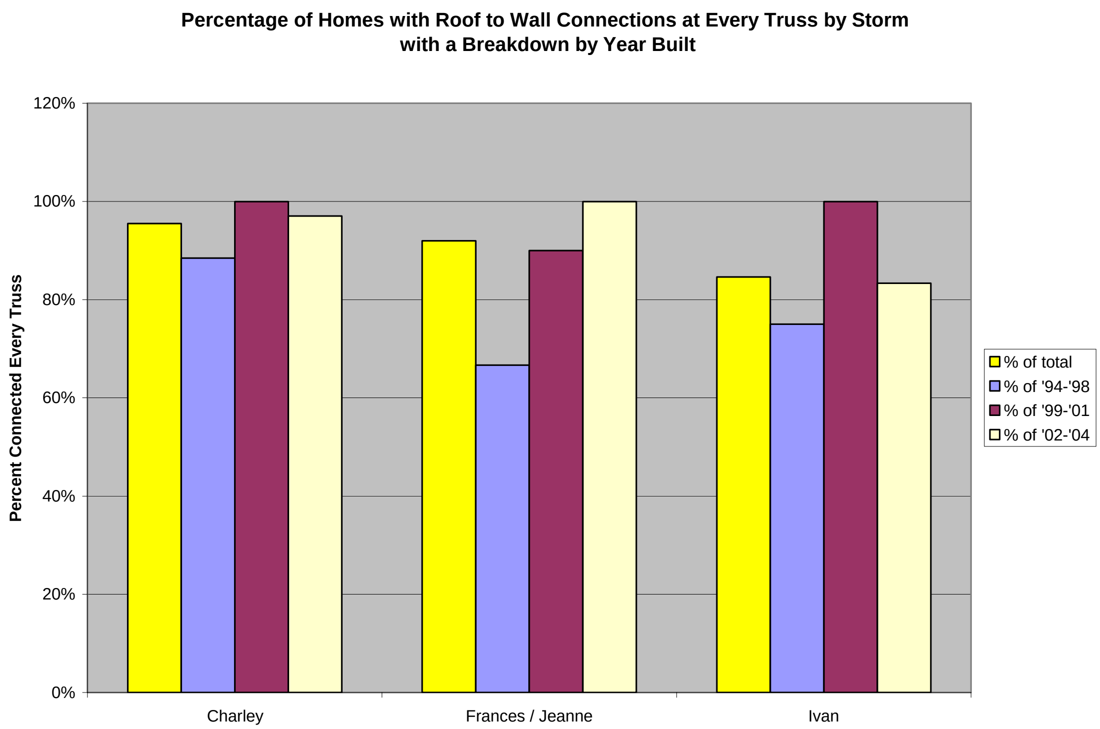

Figure 43: % of homes with roof to wall connections at every truss, by age and storm, all zones

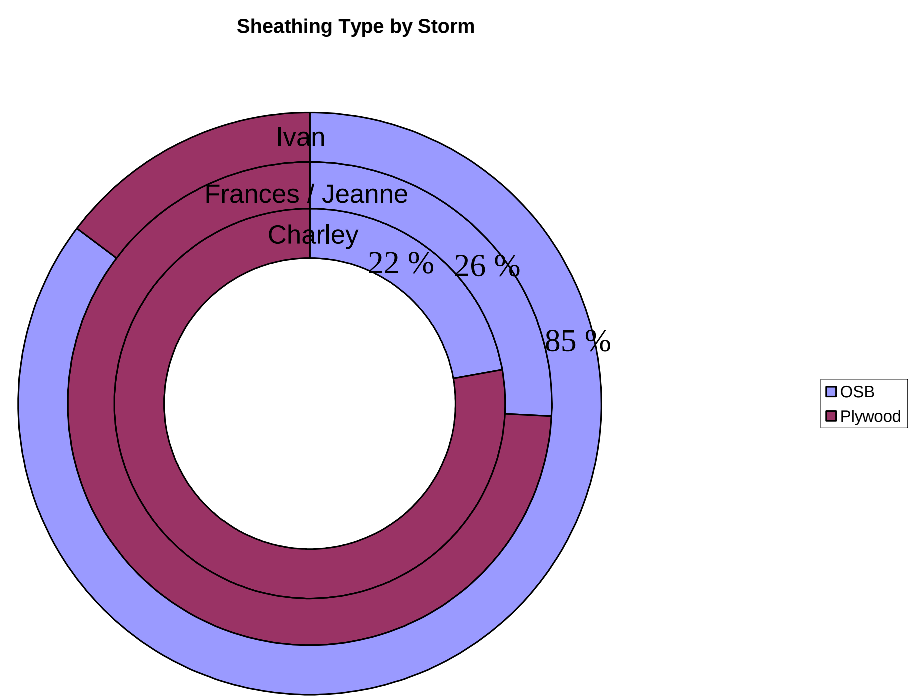

Figure 44: % of homes with plywood and OSD roof sheathing, by storm, all zones

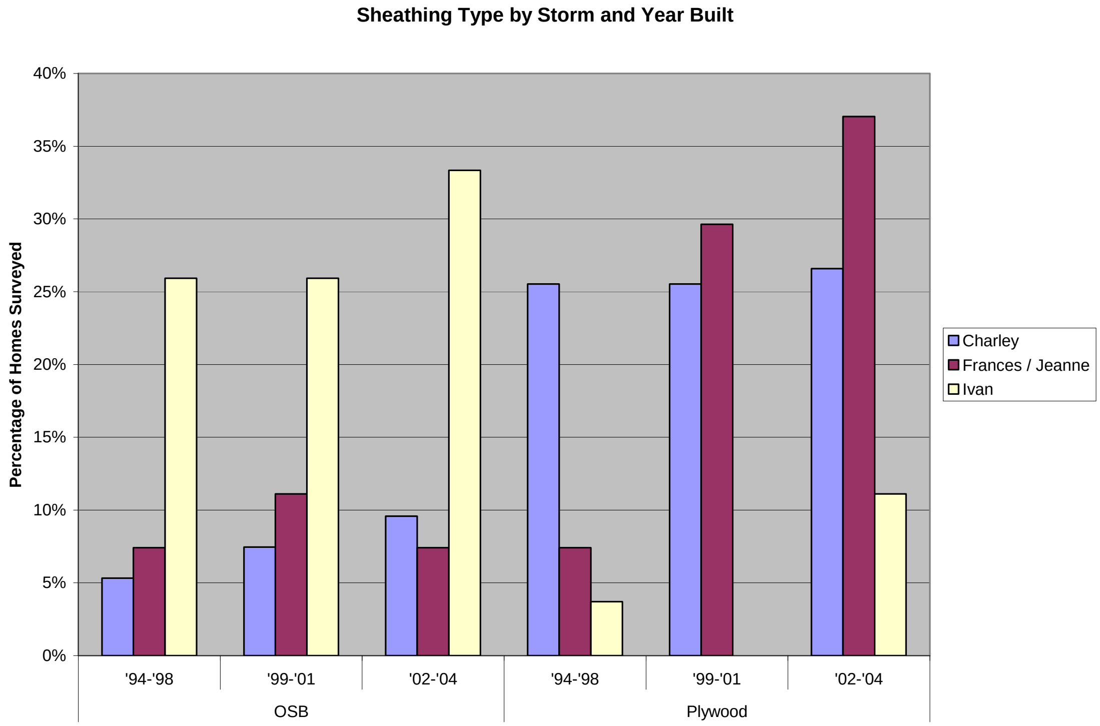

Figure 45: % sheathing type by age and storm, all zones

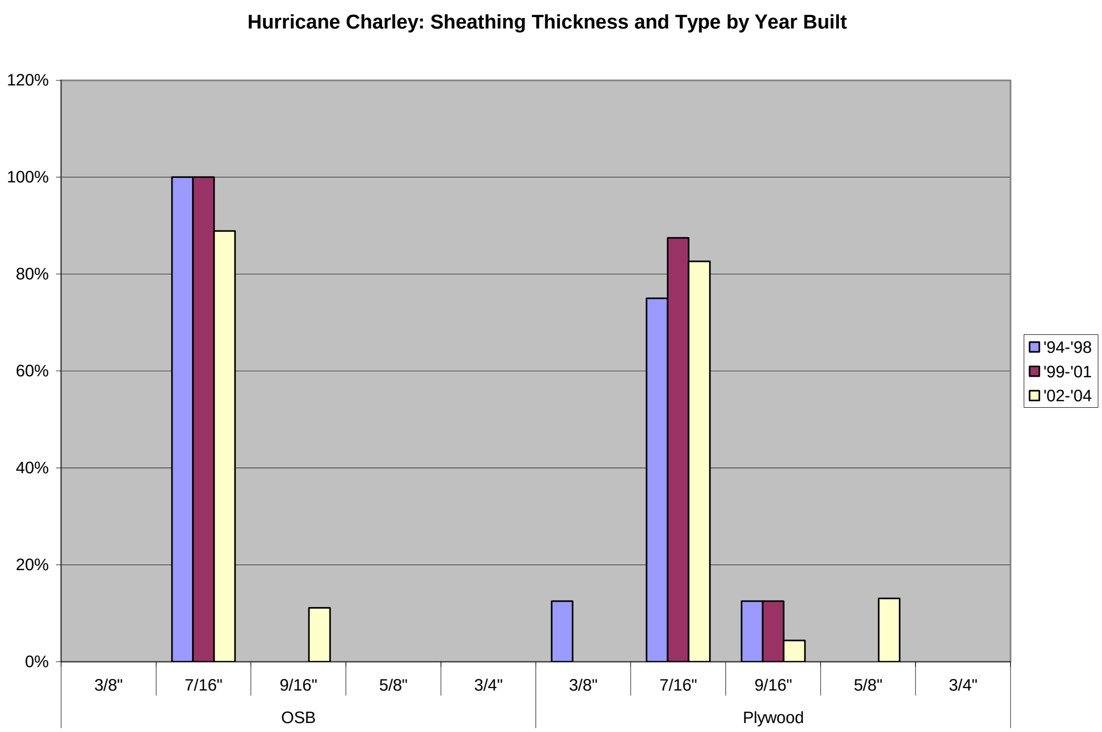

Figure 46: % of sheathing thickness by type and age, Charley

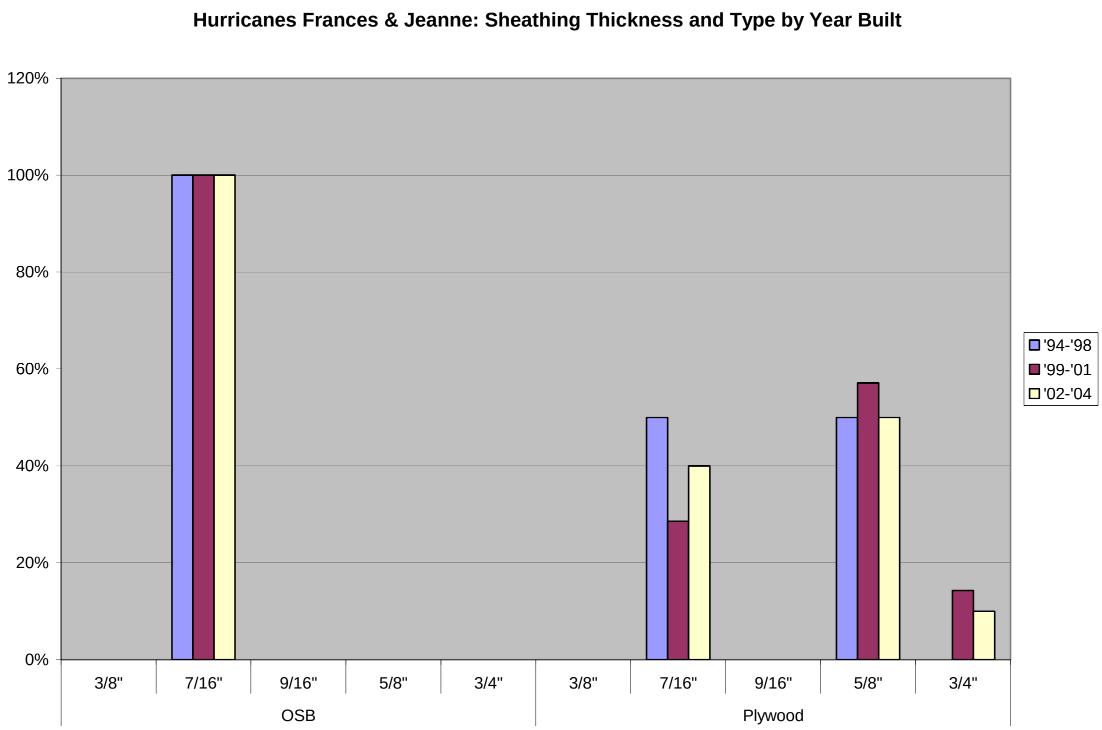

Figure 47: % of sheathing thickness by type and age, Frances & Jeanne

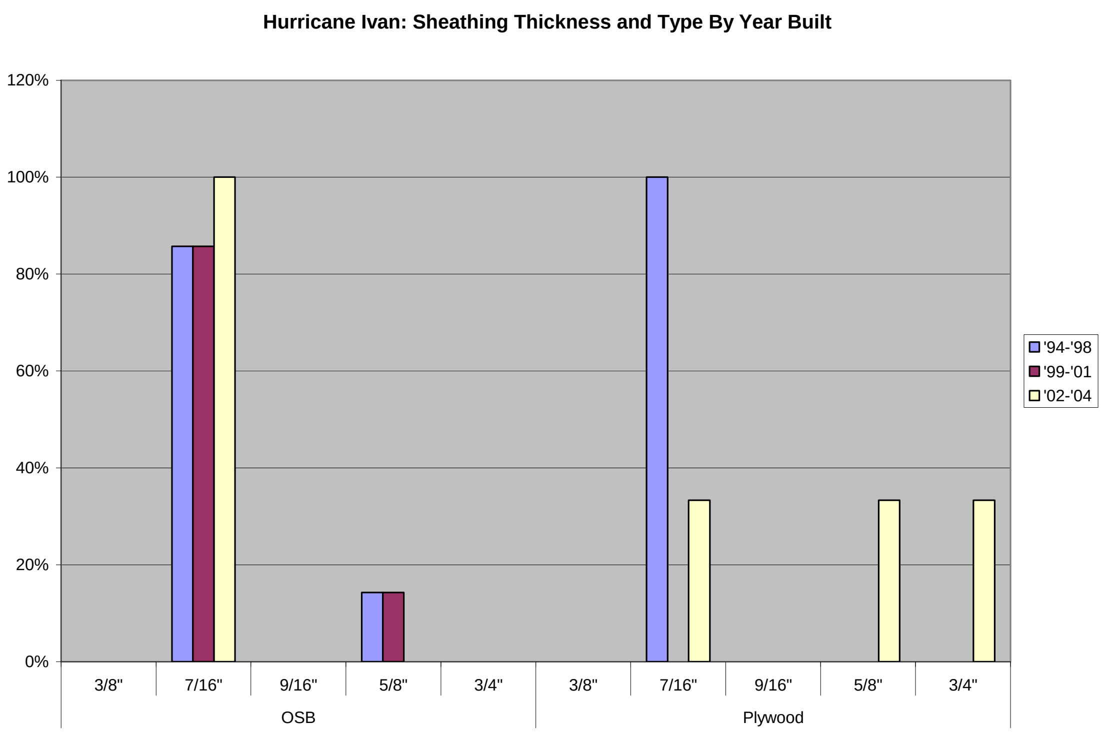

Figure 48: % of sheathing thickness by type and age, Ivan

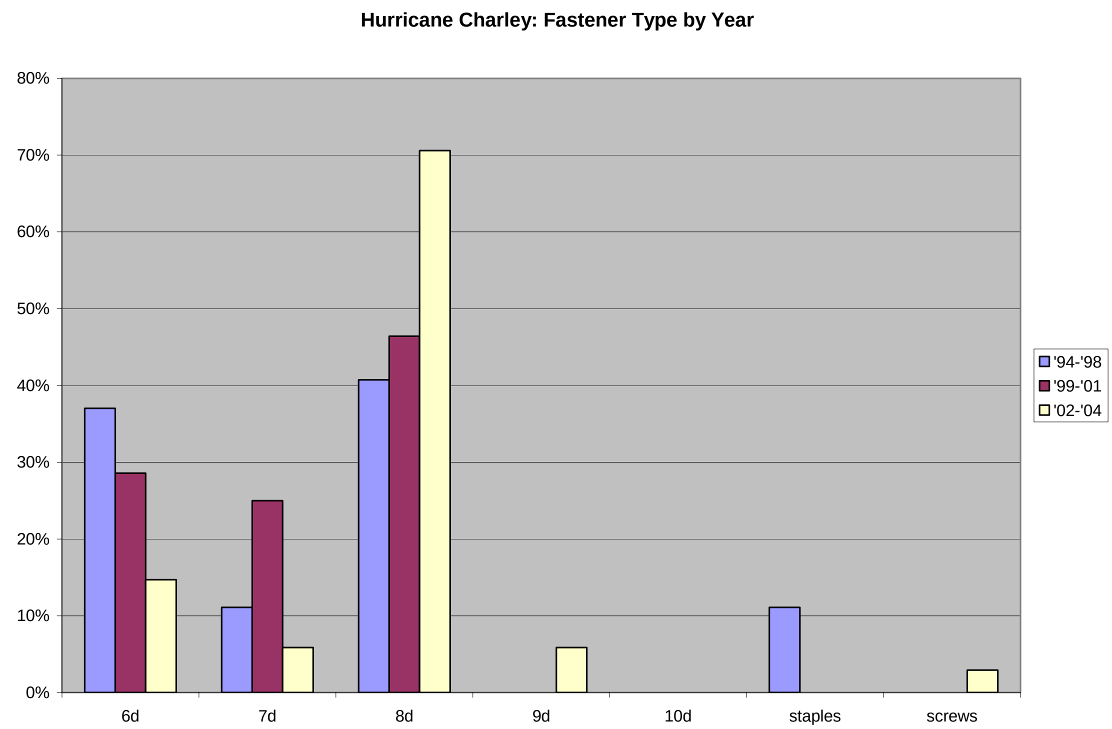

Figure 49: % sheathing fastener size by age, Charley

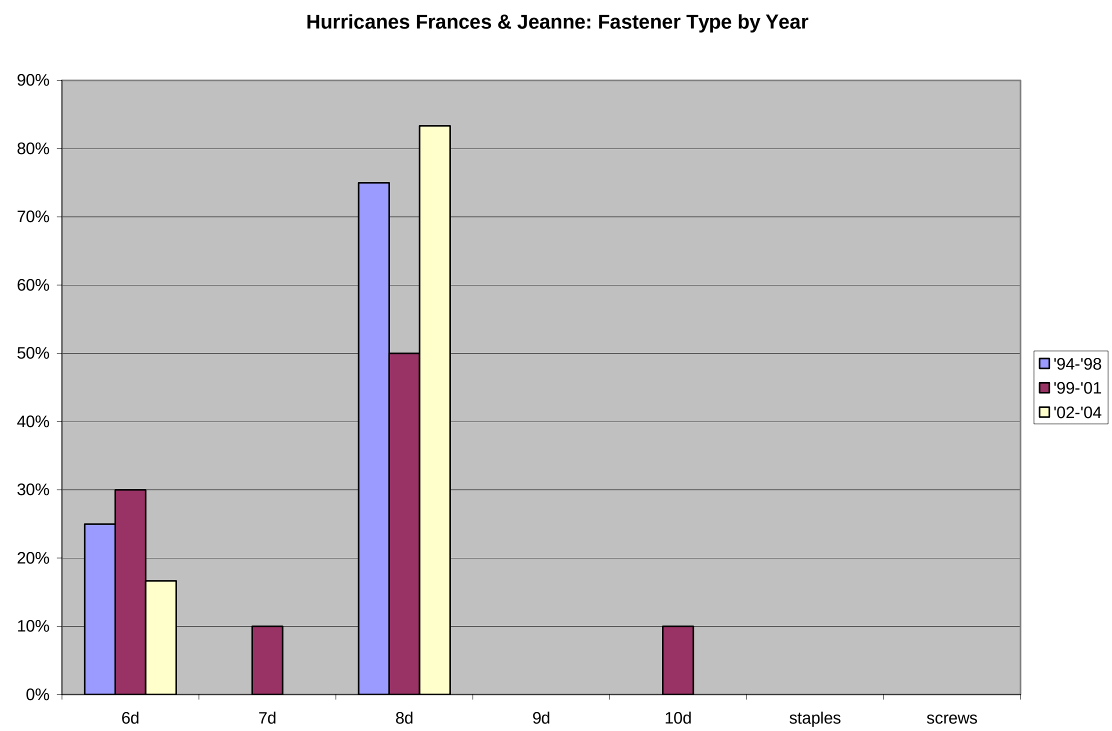

Figure 50: % sheathing fastener size by age, Frances & Jeanne

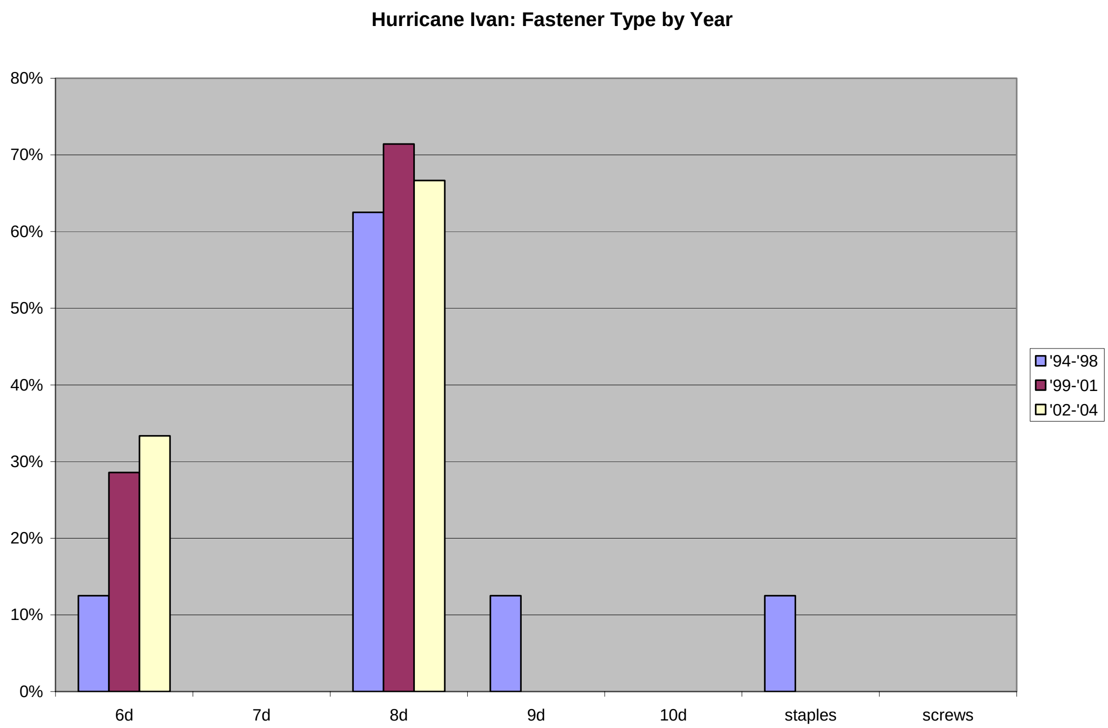

Figure 51: % sheathing fastener size by age, Ivan

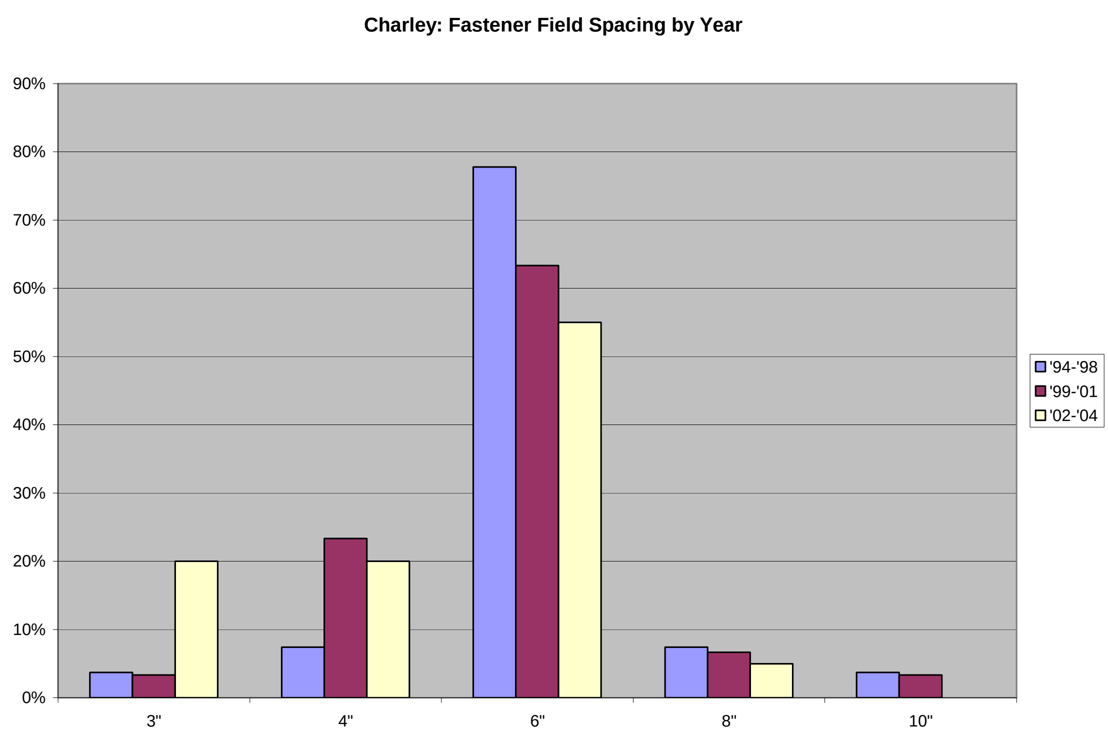

Figure 52: % sheathing field nail spacing by age, Charley

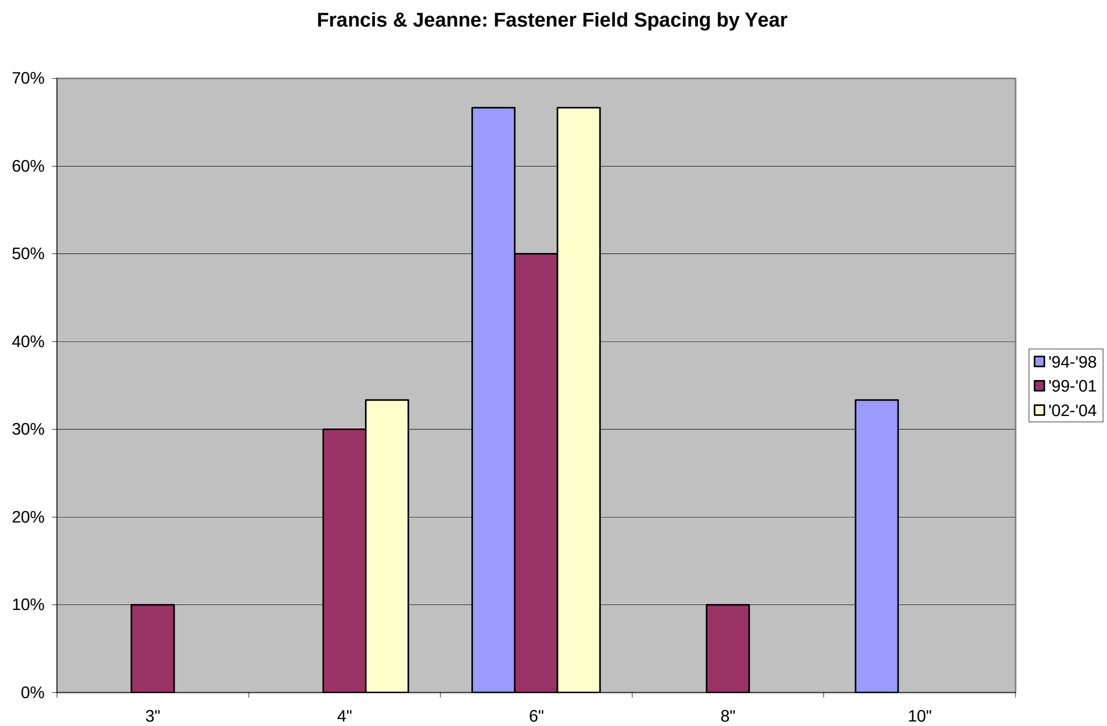

Figure 53: % sheathing field nail spacing by age, Frances & Jeanne

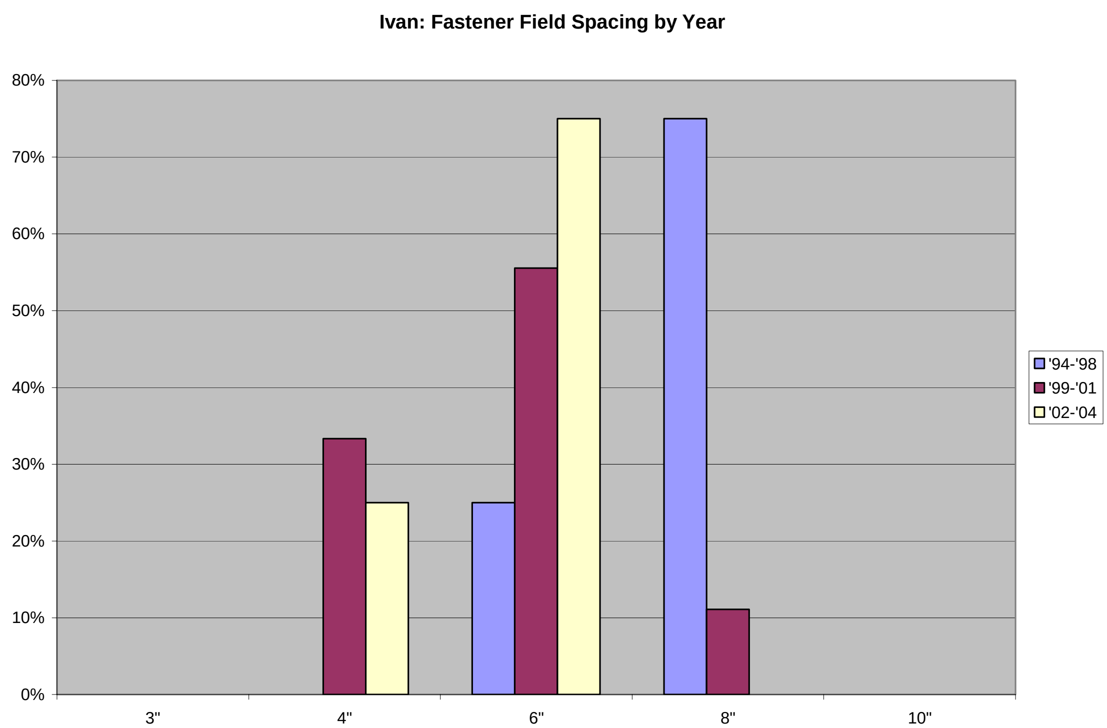

Figure 54: % sheathing field nail spacing by age, Ivan