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Disaster Mitigation

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Objective

- Inform our colleagues in industry of the academic research being conducted which impacts their profession.
- Establish partnerships with industry as we develop our research.
- Find ways to use what we have learned to increase voluntary hazard mitigation.

Research Agenda

- Interdisciplinary in scope.
  - Economics
  - Civil Engineering
  - Meteorology
  - Psychology
  - Sociology

Research Agenda

- Academic Partner Institutions

  Economics:

  - Austin College
  - University of Oklahoma
  - Texas Tech University
  - East Carolina University

  Engineering:

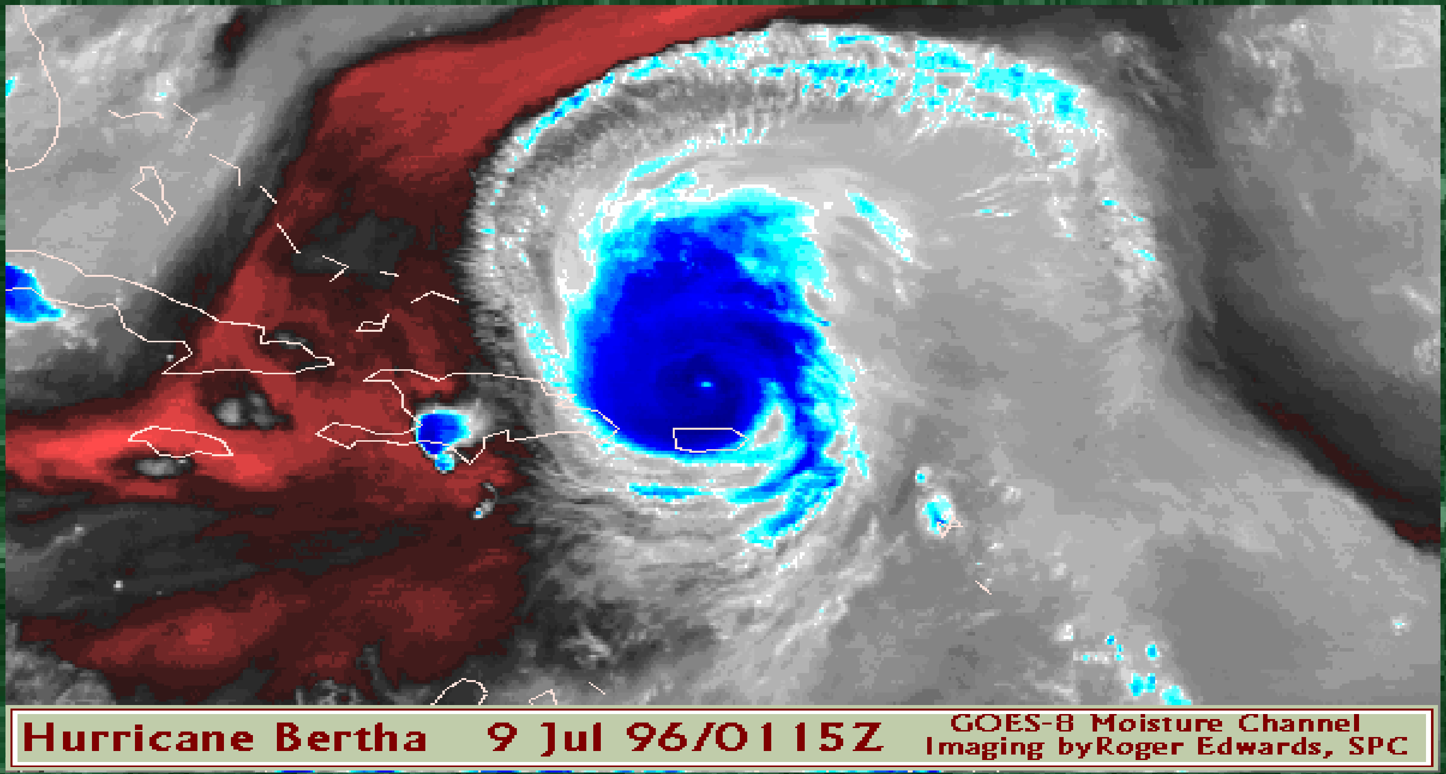
  - Texas Tech University

  Meteorology:

  - University of Oklahoma

Research Agenda

- Hurricane Mitigation Research
- Tornado Mitigation Research



Mitigation

- The theory behind disaster mitigation is a simple one: by making an investment of time, money and planning prior to the occurrence of natural disasters, there can be tremendous savings that result from reducing the impact of natural disasters when they inevitably occur. Brenner (1993)

Does Mitigation Matter?

- Habitation of threatened areas has increased.
- Even smaller storms can cause large damage.
- Engineering studies have consistently shown that inexpensive measures can have a large effect on damage reduction.

Carrot or Stick?

- Can market forces accomplish effective mitigation or is coercive policy the only option we have?

Jarrell, TX Tornado 27 May 97 2032Z
Tornado at photo time (3:32 pm CDT) is about 1 mi N of Jarrell, headed into town, as documented by storm chaser Lon Curtis. Image used by permission.

Increased Regulation
Let's try the stick!

- Discourage or disallow development of high-risk areas.
- Strictly enforced sufficient building codes.
- Increased building code standards.

Can we trust the market? Let’s try the carrot!

- For a market to function, there must be a demand for the product.
- Policy assumptions regarding mitigation was that little or no demand existed for mitigation measures.
- Without demand, reliance on market solutions is therefore futile.

What Does the Research Tell Us?

- Effectiveness of government mitigation programs (Oklahoma Saferoom Initiative)
- Effectiveness of new building codes (Florida)
- Effectiveness of early warning systems
  (Doppler Radar)
- Market response to private mitigation alternatives

Hurricane Market Mitigation Study

- Motivation:
  - – Incorporate “societal impact” studies into research of wind related natural disasters.
- Funding:
  - – National Science Foundation
    - Cooperative Project in Wind Engineering
    - Grant # CMS9409869
  - – Additional Funding from FEMA

Hurricane Market Mitigation Study

- Examine the value of mitigation from three perspectives.
  - -Theoretical
  - -Empirical
  - -Experimental

Hurricane Market Mitigation Study - Theory

- Purpose:
  - Theoretical studies attempt to create a mathematical model of human behavior and then examine how the model responds to changes in some of the variables in the model.

Hurricane Market Mitigation Study - Theory

- Basic Theory: Dixit (1990), ***Optimization in Economic Theory***.

  Result: With full insurance, there is no value to mitigation.
- Modified Theory: Simmons and Kruse (2000), ***Journal of Economics***.

  Result: Assuming deductibles and intangible losses, mitigation has a positive value.

Hurricane Market Mitigation Study - Empirical Study

- Purpose:
  – Empirical studies collect data which can show researchers the actual effect of decisions made by individuals.

Hurricane Market Mitigation Study - Empirical Study

- Location: Galveston, Texas
- Hurricanes on Galveston Island:
  - Galveston has a long history including two of the most deadly hurricanes ever recorded.
- Data:
  - MLS sales data from 1992 to 1997
  - Historical hurricane data from the National Hurricane Center

Hurricane Mitigation Study
Empirical Study

- Two separate measures of mitigation were studied.
  - Eng. Assessment of the survivability of one home versus another.
  - Obvious mitigation: Storm Shutters.

Hurricane Market Mitigation Study - Empirical Study Results

- Homes with obvious hurricane mitigation features sell on the market at a premium to homes without mitigation.
- This result is independent of hurricane activity, although more pronounced after an event.
- Homes with a greater resistance to wind forces sell on the market at a premium to homes with lower resistance to wind forces.

Hurricane Market Mitigation Study - Empirical Study

- Simmons and Willner (2001), ***Atlantic Economic Journal***.
- Simmons, Kruse and Smith (2002), ***Southern Economic Journal***.
- Simmons and Willner (2002), ***Journal of Economics and Business Studies***.

Hurricane Market Mitigation Study - Experimental Study

- Purpose:
  - Lab experiments are new to economics. Similar to lab experiments in the social sciences, the intent is to replicate human behavior in a laboratory setting similar to decisions made in everyday life.

Hurricane Market Mitigation Study - Experimental Study

- Procedure:
  - Study subjects were given a coupon worth actual money if they survived a lottery.
  - Prior to the lottery, they could purchase "mitigation" which would protect them in the lottery.
  - Several rounds were performed at "hit" probabilities ranging from 1% to 20%.

Hurricane Market Mitigation Study - Experimental Study Results

- Market price of mitigation exceeds expected value.
- Willingness to purchase mitigation increases as perceived risk increases.
- Willingness to purchase mitigation is independent of previous losses.

Hurricane Market Mitigation Study - Experimental Study

- Simmons and Kruse (2003), *Proceedings: 11th International Conference on Wind Engineering*.
- Simmons and Kruse (2004), <u>Wind and Economics</u>.

Hurricane Market Mitigation Study - Conclusions

- Contrary to previous research, hurricane mitigation does appear to have value to residents in high-risk areas.
- This value persists despite fluctuations in hurricane activity.

Hurricane Charley Building Code Performance

Project Overview

- Examine types of damage suffered by residential dwellings in Charlotte County
- Examine the effect of increased wind pressure on economic damages
- Examine the effect that various building code regimes had on economic damages
- Estimate *actual* avoided damages from better construction
- Estimate *potential* avoided damages from better construction

Data

- Data for this study was compiled by IBHS and obtained from county tax assessment rolls and building permit data
- Dataset contains information on over 53,000 residential dwellings in Charlotte County

Damage Variables

- Building permits issued in the 8 months after Hurricane Charley provides the basis for damage types
- There are 12 different types of permits
- These are summarized into 5 sub-categories: Internal, Roof, External, Residential Cage Enclosure, and Carport

Wind Field Data

- An estimate of the peak winds for each home is provided
- This estimate is divided into 5 categories:
  - Less than 120 mph
  - 120-129 mph
  - 130-139 mph
  - 140-149 mph
  - Greater than 149 mph

Year Built Categories

- Using the homes year of construction a series of 4 categories were derived to evaluate the impact of prevailing construction practices and building codes.
  - Pre 1980
  - 1980-1996
  - 1997-2002
  - Post 2002

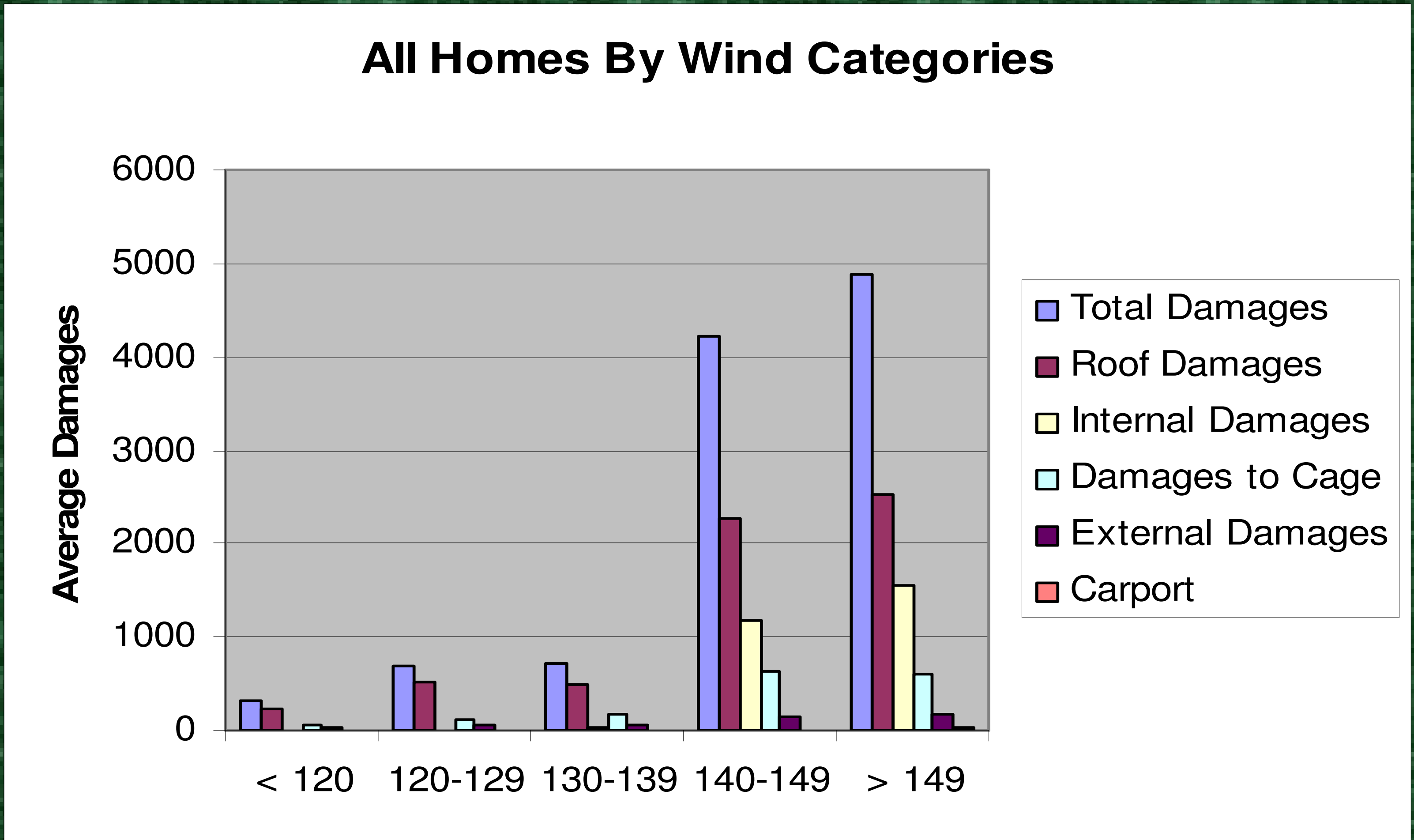
Outliers and Missing Data

- Some observations were removed due to a suspicion of data entry error.
  - Example: Roof repair at $1,000 per square foot
  - Example: Internal repairs in excess of $1,000,000 on a home assessed at $150,000

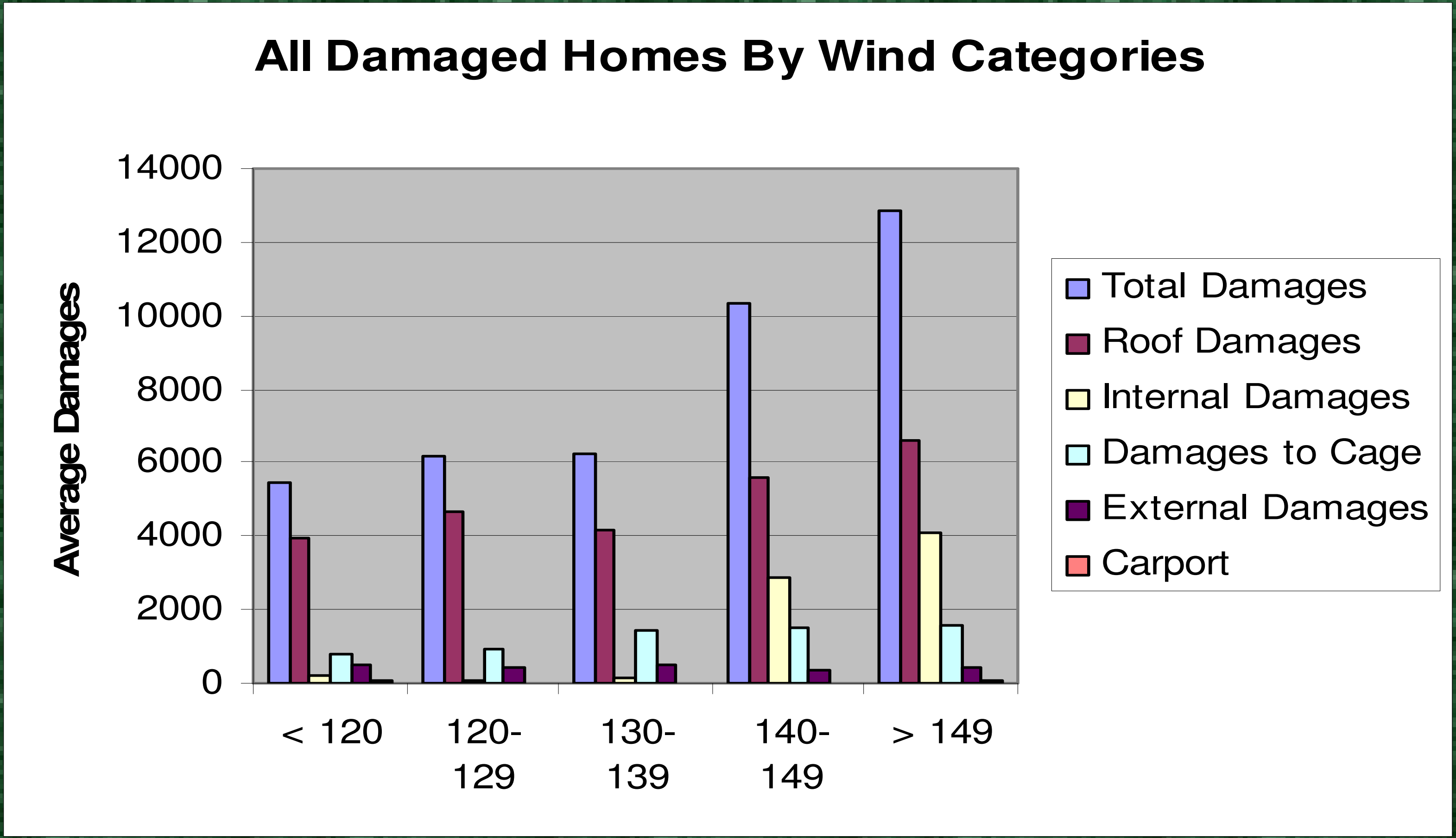
Damage Analysis

- We derived average damage values for each damage category and total damage across 4 views of the data
  - All Homes (53,000)
  - All Damaged Homes (17,000)
  - All Damaged Homes (Adjusted) (15,000)
  - All Roof Damaged Homes (13,000)
- Each view is by wind categories and then year built categories

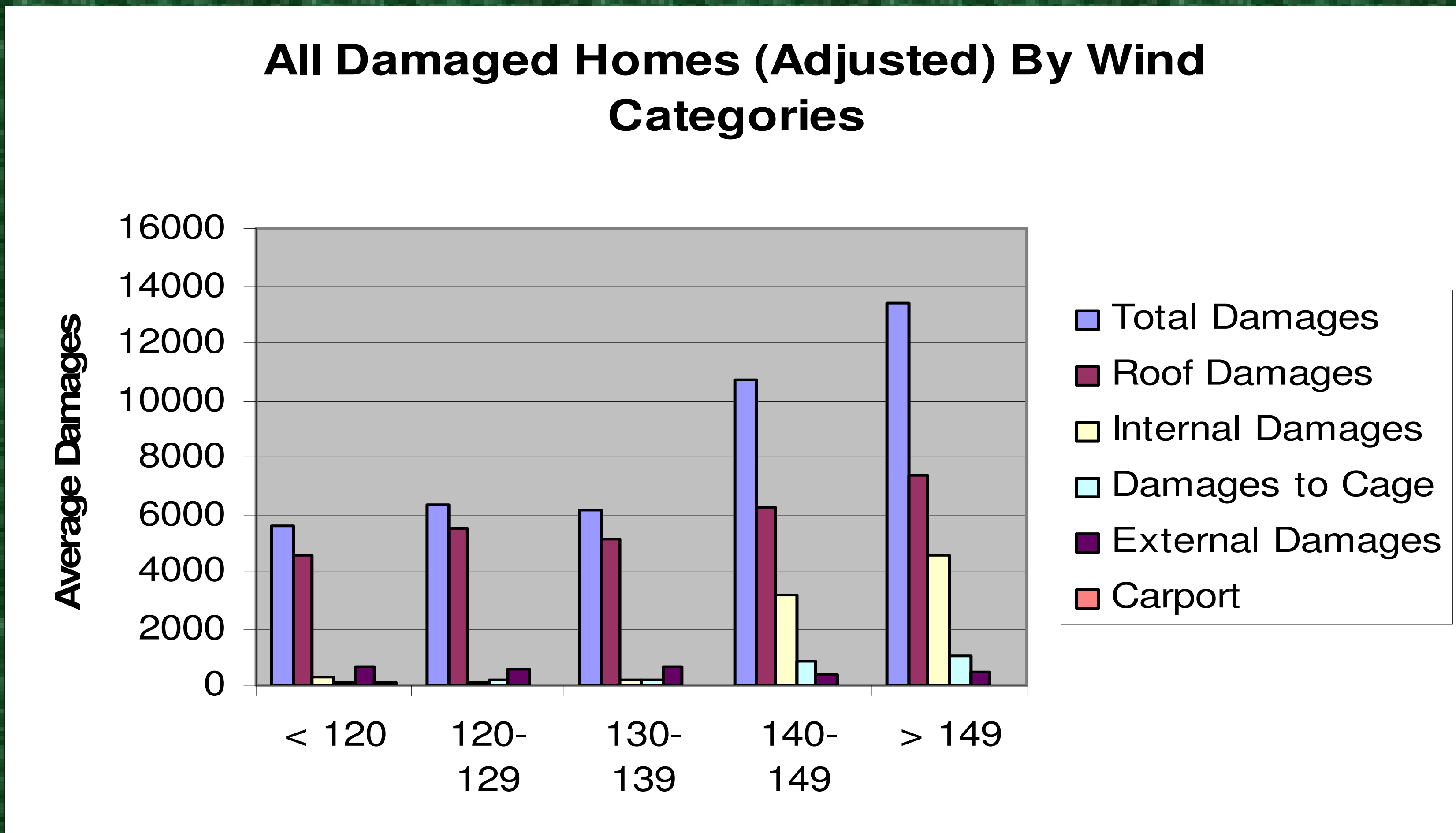
Average Damage Across All Homes By Wind Speed



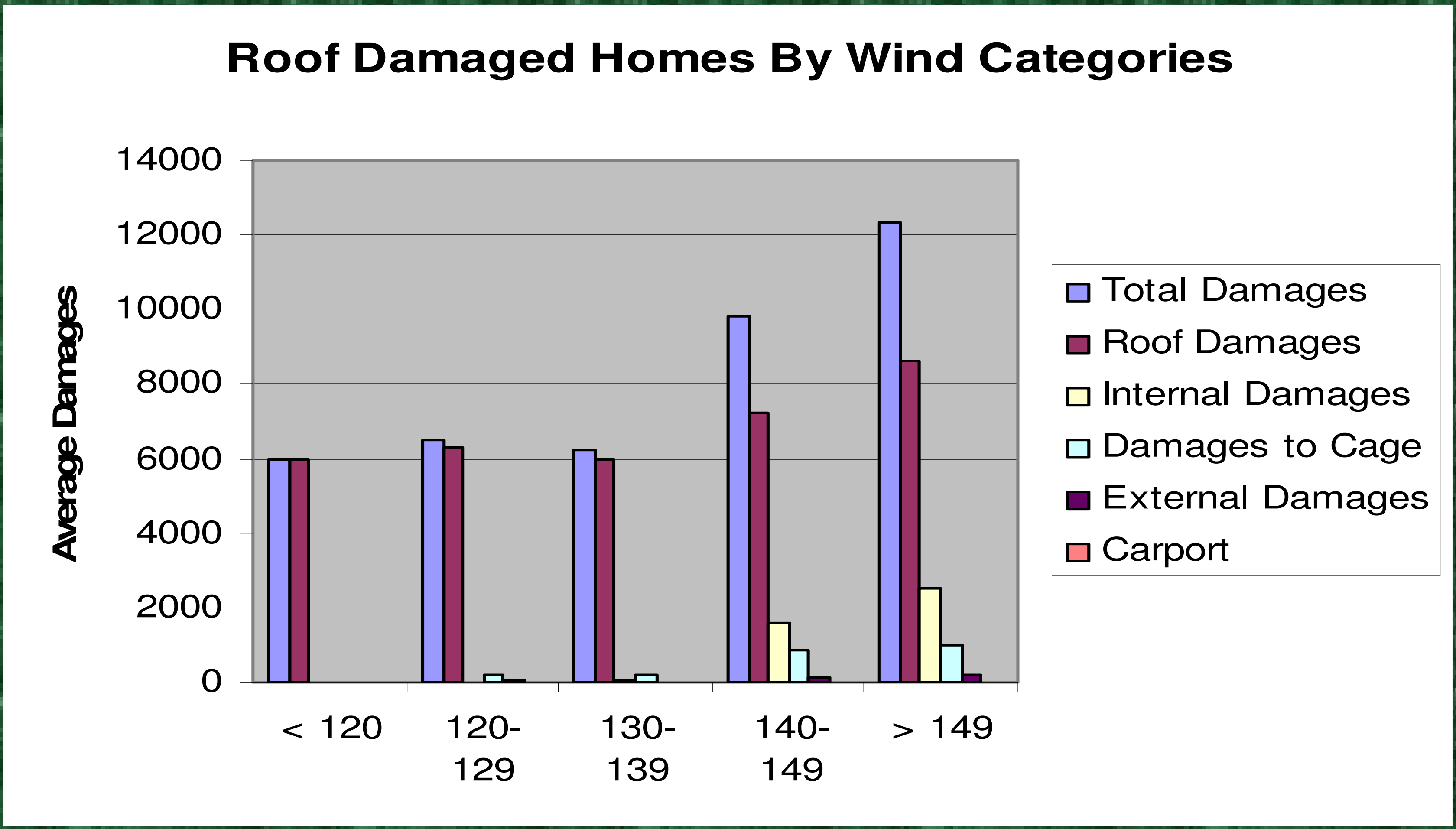
Average Damage Across All Damaged Homes By Wind Speed



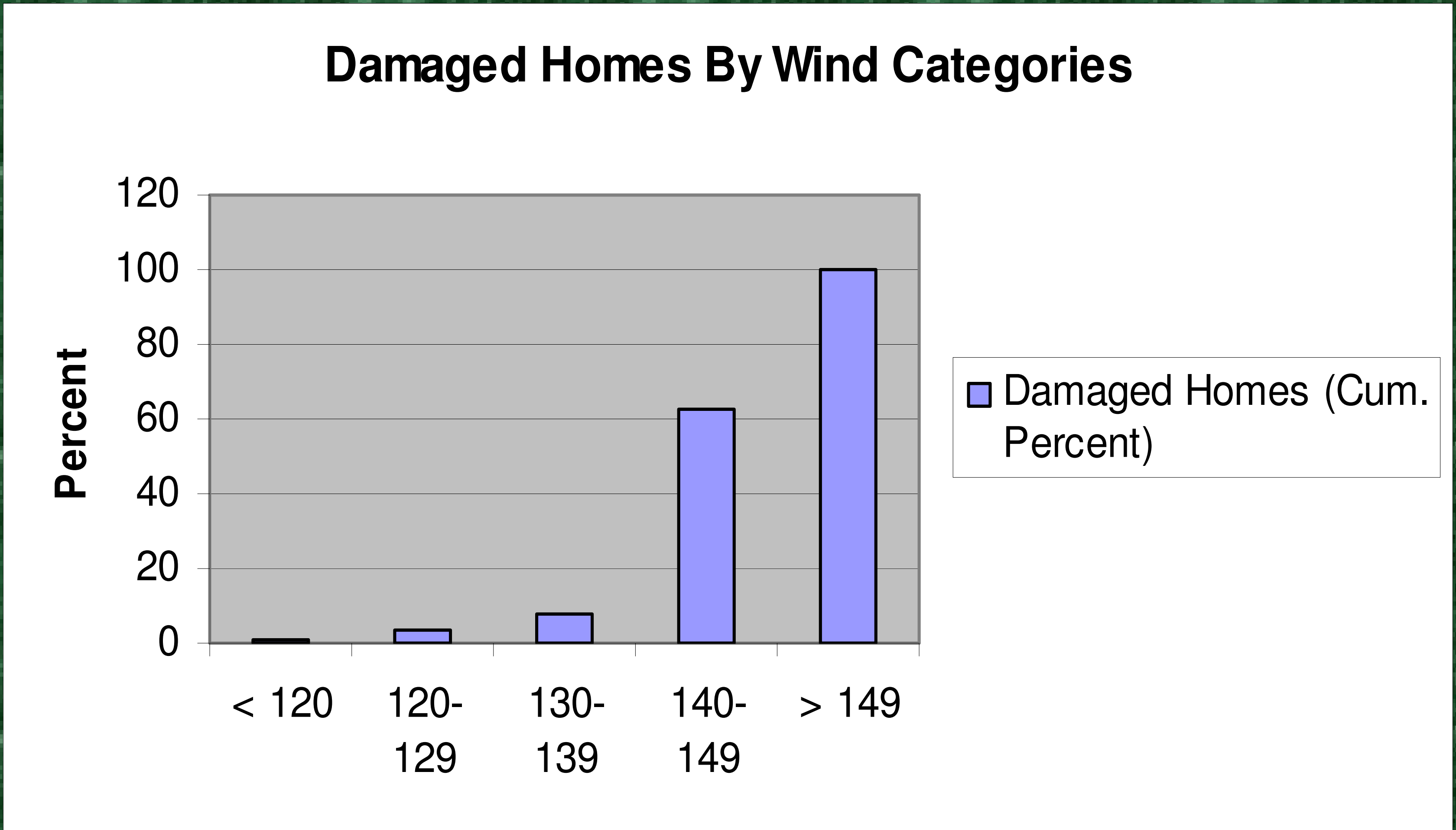
Average Damage Across All Damaged Homes (Adjusted) By Wind Speed



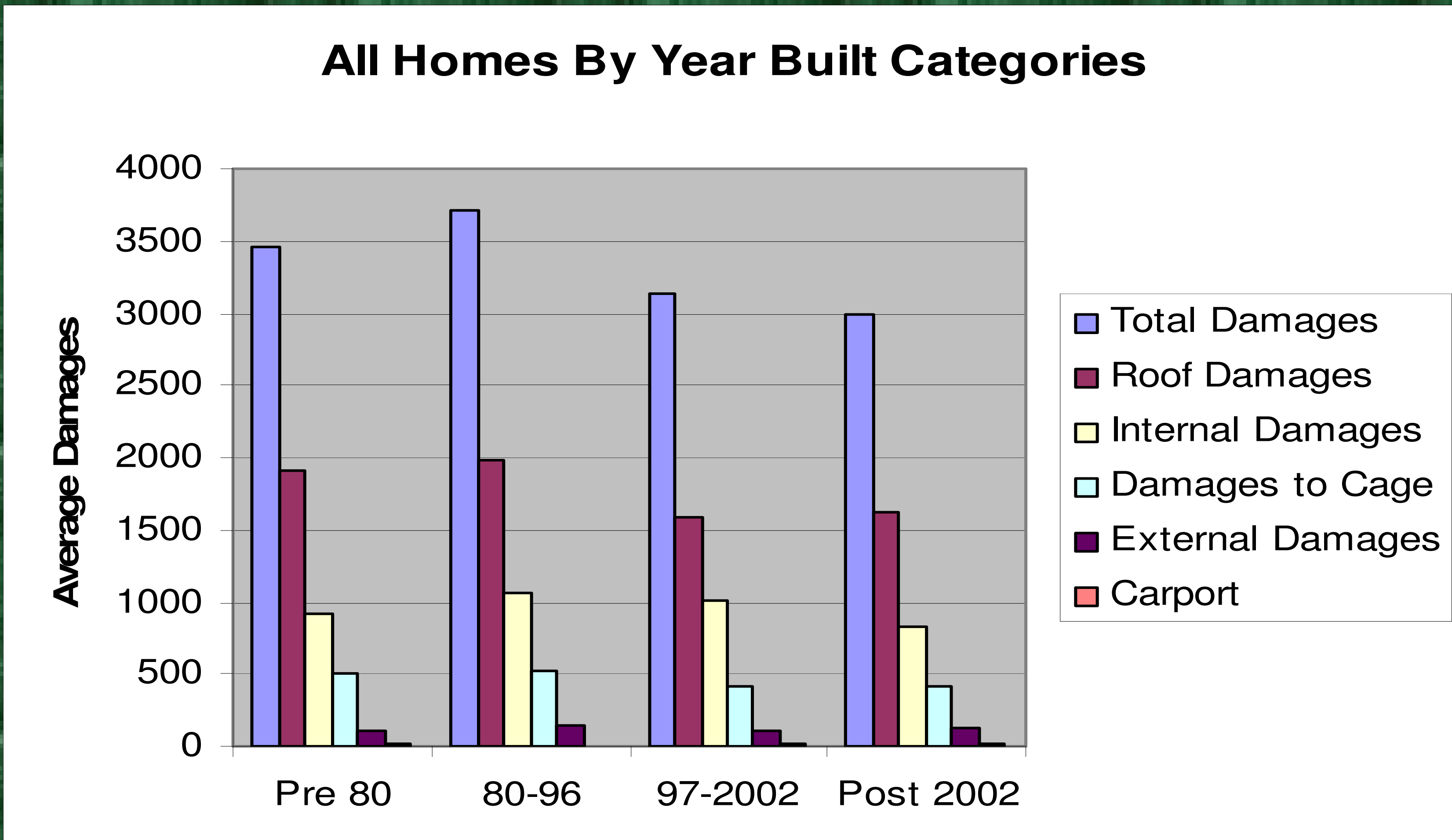
Average Damage Across Roof Damaged Homes By Wind Speed



Overall Effect of Wind Speed on Damages



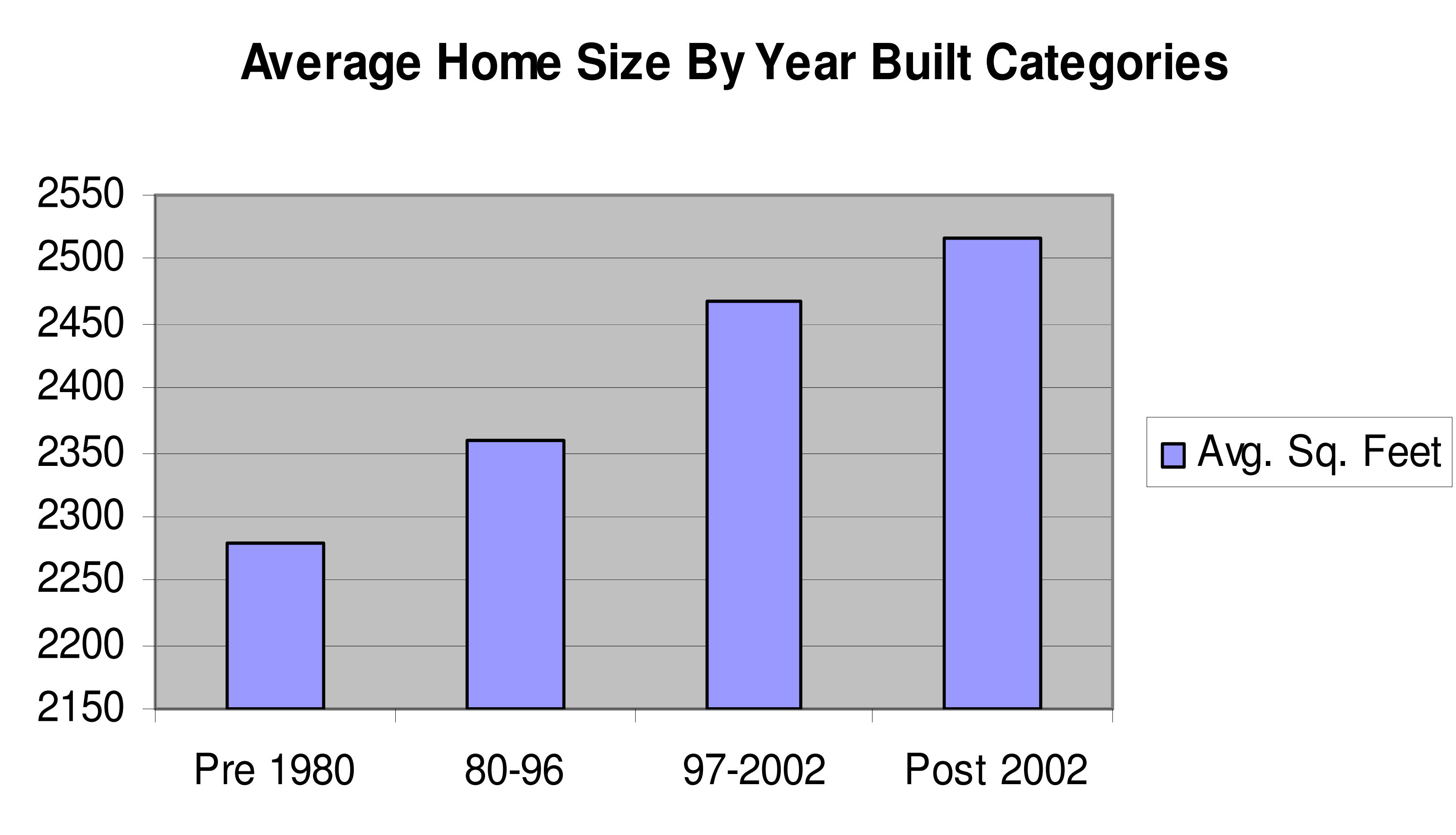
Average Damage Across All Homes By Year Built Categories



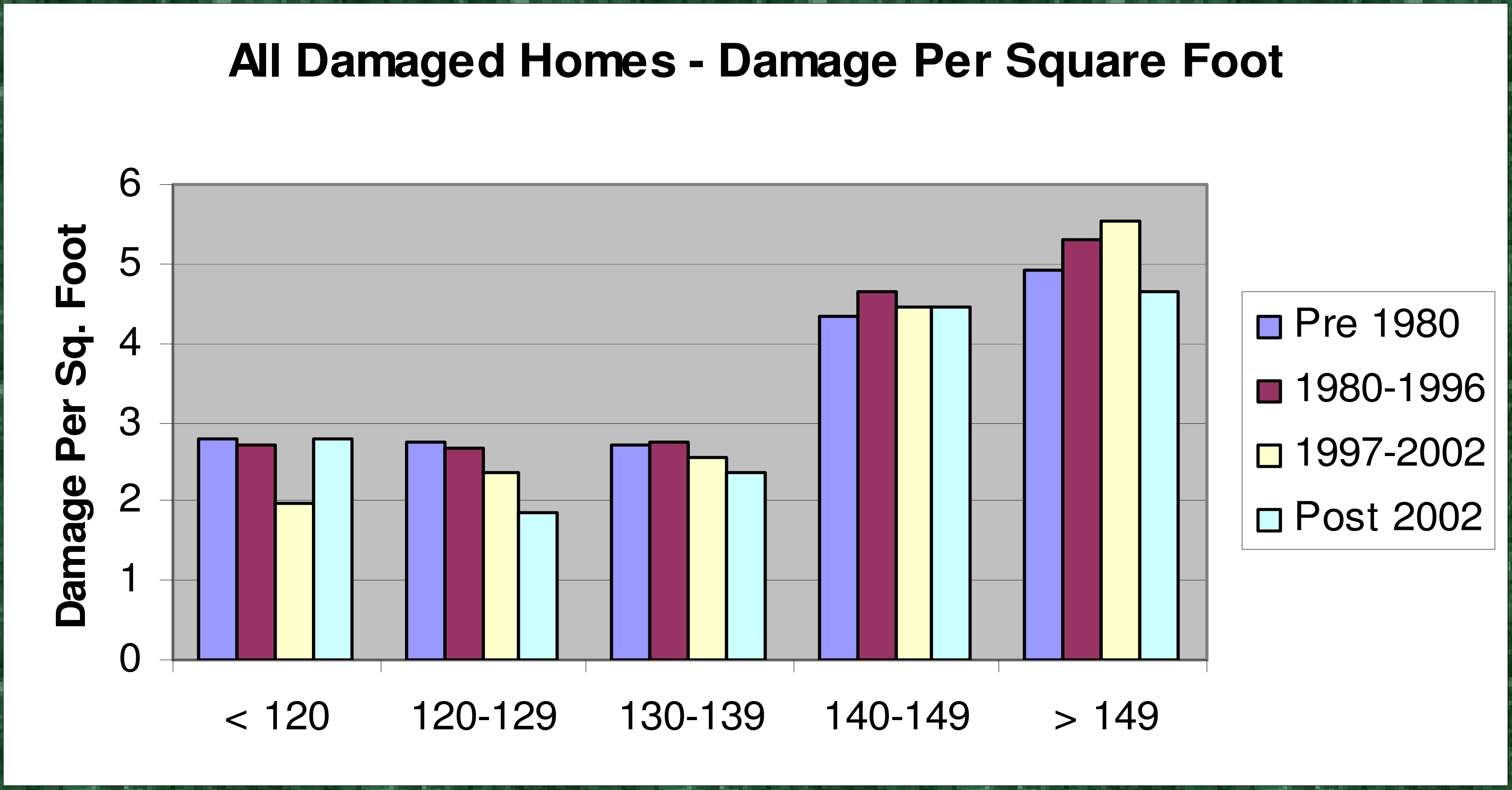
Effect of Year Built

- While the effect of higher wind speed on damage is obvious, year built does not appear to have an overwhelming influence.

Average Home Size By Year Built Categories



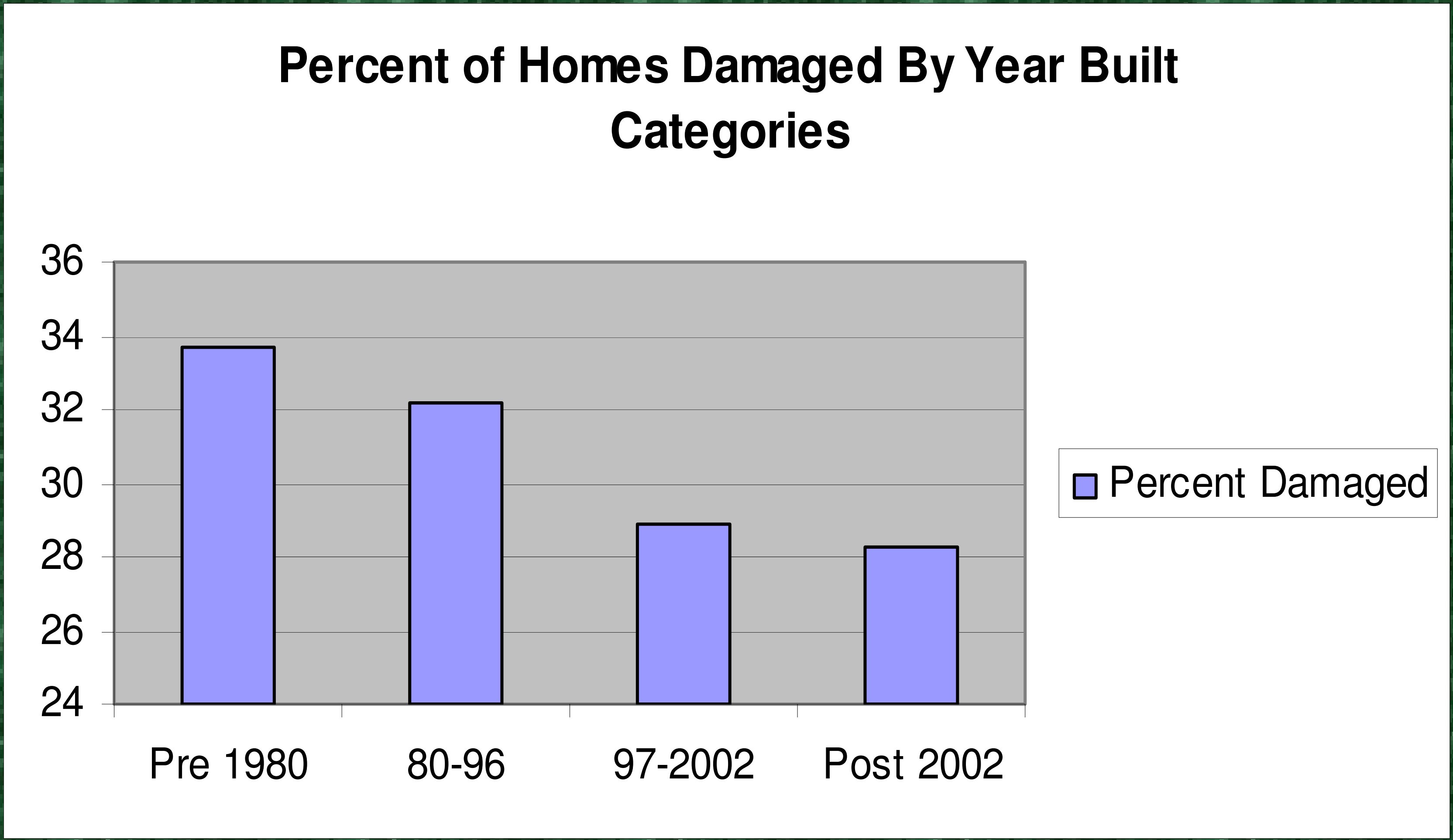
All Damaged Homes – Damage Per Square Foot By Wind Speed



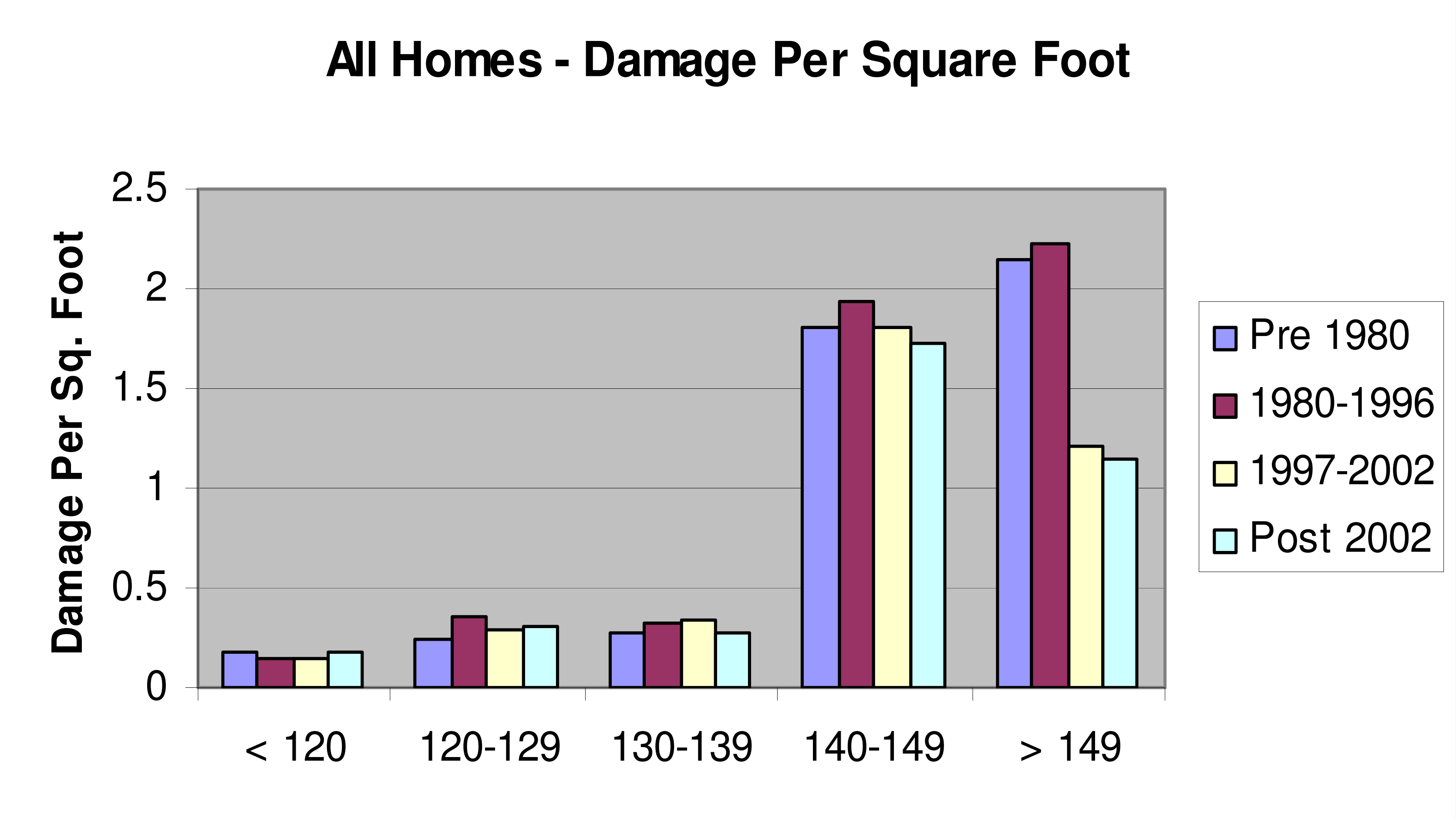
Effect of Year Built

- While damage per square foot makes a better case than simple averages, particularly for Post 2002 construction, something else could be important.

Damaged Homes (Percent) By Year Built Categories



All Homes – Damage Per Square Foot



Estimated Economic Impact of Post 1996 Construction

- We can estimate the effect of better construction by taking the avg. damage per square foot of homes built before 1996 for each Wind Category and applying that to homes built since 1996 for each category.
- Based on this, enhanced construction reduced damages from this storm by as much as $14 million

Potential Economic Impact of Better Construction

- Using the same method we can estimate what the reduction in damages would have been if the best construction practices were in place in all homes.
- Potential damage reduction, based on this method, would have been as much as $46 million or 25% less than the permit value of $182 million

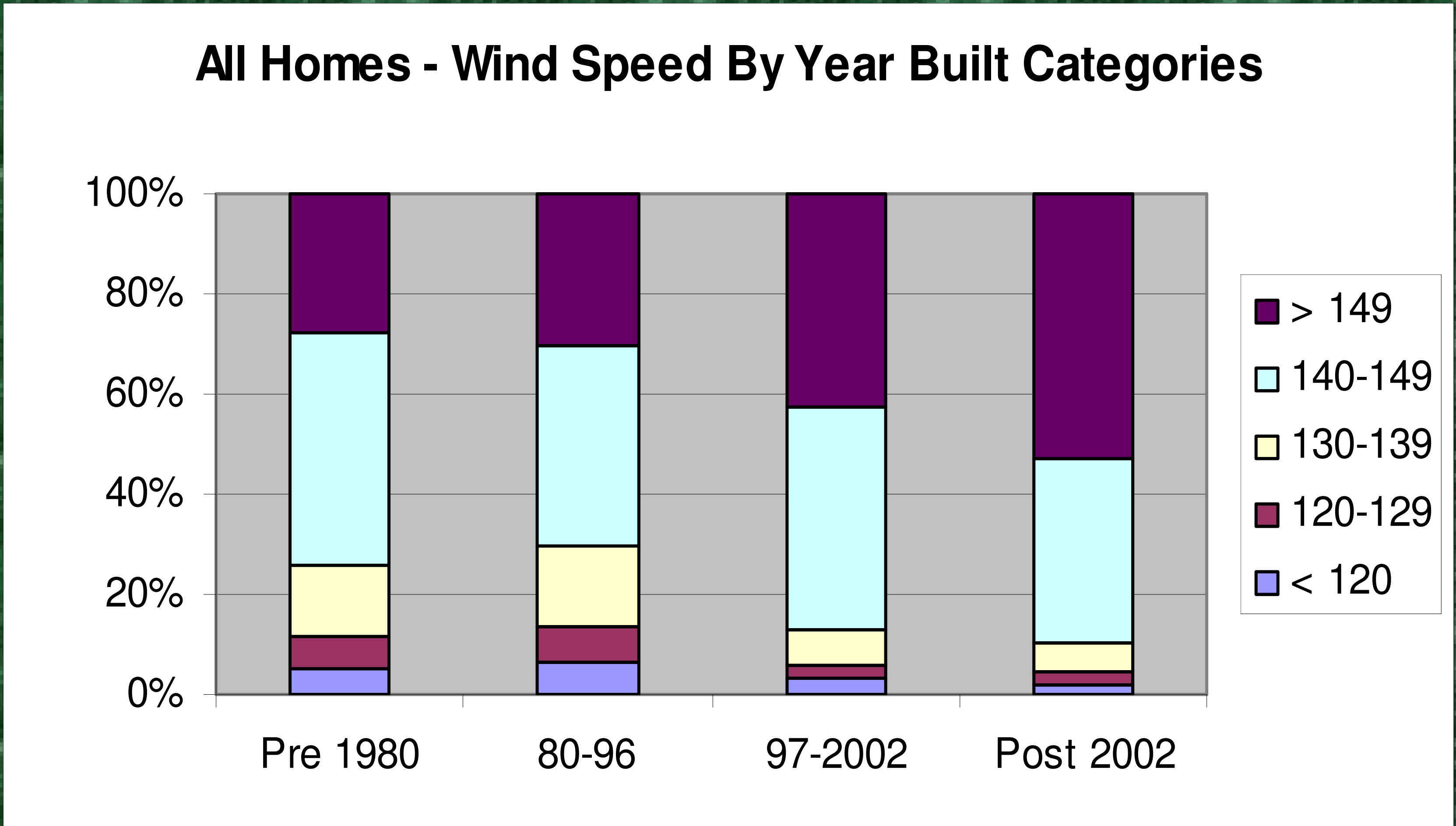
Potential Economic Impact of Better Construction

- Another useful comparison is to look at the difference between what estimated damages would be if all homes had been built to the best standards vs. all homes built to the worst standards. Estimated damage if all homes were built to the worst standards would be $201 million vs. $142 million if all homes are built to the best standards. This is a difference of $59 million or almost 30%.

Skeptics Turn

- It can be argued that the decrease in damages for newer homes is simply the result that newer homes are located in areas which had lower wind speeds since wind is the predominant predictor of damage

Wind Speed By Year Built Categories



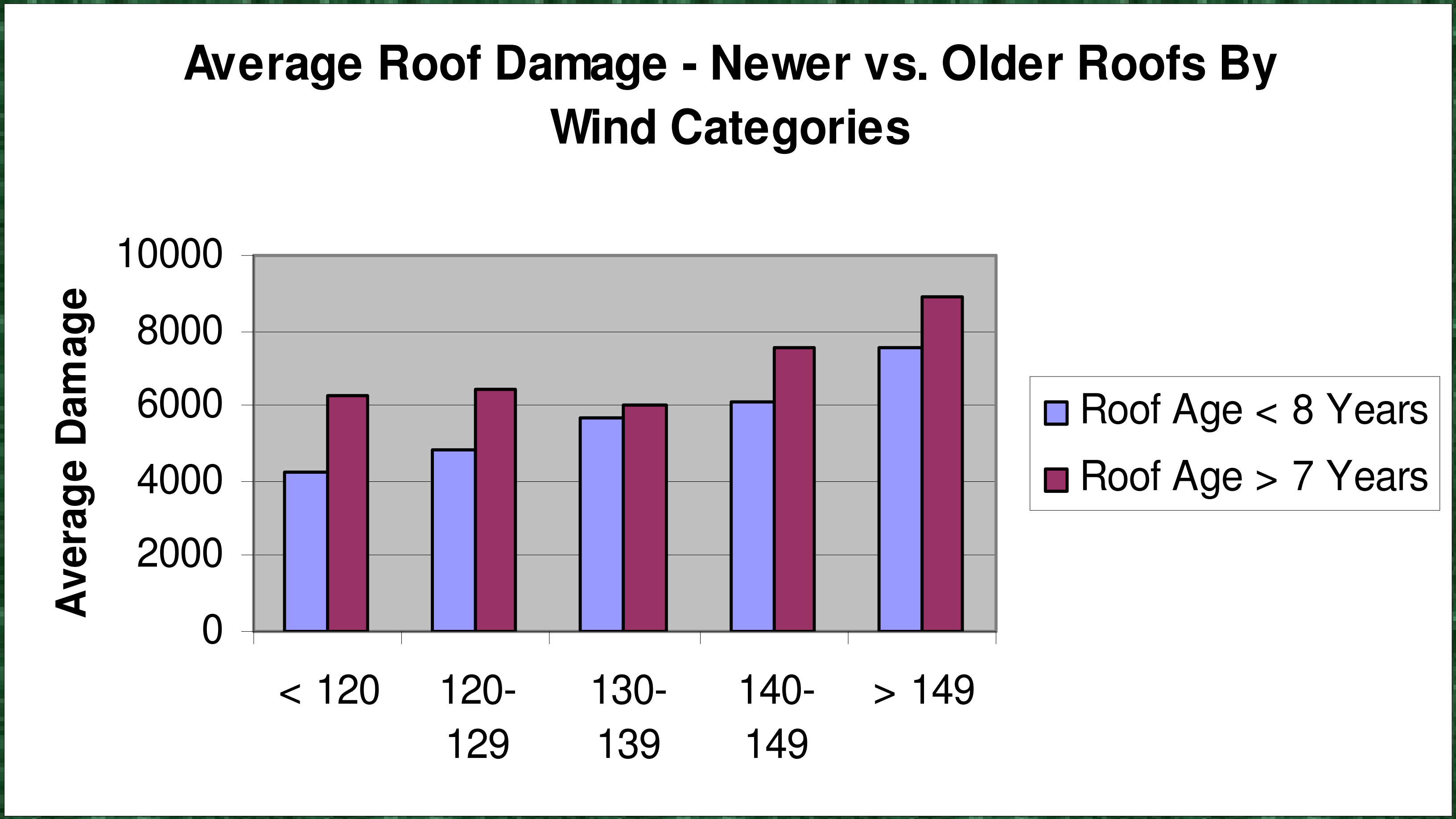
Study Conclusions

- Largest Determinant of Damage was Wind Speed
  - Damages increase significantly at peak wind speeds in excess of 140 mph
- Year Built Does Have a significant impact on damages
  - Homes built between 1980-1996 did not fare as well as Pre 1980 homes
  - Homes built after 1996 fared better with the homes built after 2002 doing the best

Project Extension

- Some possible extensions are to look at more detailed analysis of damage variables
- Example: Roof Aging Study
  - Pre Charley Roof Permits were also on the dataset.
  - Using these permits, we were able to estimate the age of the pre-Charley roof
- By charting the damage by age, we found a natural break at roofs older than 7 years

Average Roof Damage – Newer vs. Older Roofs By Wind Categories



Econometric Damage Analysis

- Econometric models allow a more sophisticated method to examine damage and the interrelationship among variables
- Example: We can determine the incremental effect of variables instead of just averages
- Interaction effects among the variables can be examined

Structural Variables

- The dataset contains information on several structural elements of each residence
- Exterior Walls: 23 different types
- Roof Type: 12 different types
- Roof Covering: 15 different types

Econometric Damage Function

- Having information on the structural elements of each home enables us to construct a damage function
- Damage functions can examine the incremental effects of a variety of independent variables on a dependent variable, in this case, damage

Econometric Damage Function

- One Possible Regression Equation:

  Damage = f (Wind, Year Built Category, Type of Exterior Wall, Type of Roof, Type of Roof Covering, Age of Roof, Age of the Structure)

Econometric Damage Function

- Potential results can reveal subtle relationships among the various components contained within each structure and the resulting damage

Tornado Mitigation

- Analysis of Market and Policy actions following 1999 Oklahoma tornadoes.
- Analysis of the effect of Doppler Radar on Injuries and Fatalities.
- Market Acceptance of tornado mitigation.
  - ICLR Funded student project (Austin College)
  - ICLR Funded real estate sales project. (OU)

Tornado Mitigation Market Analysis

- New homes constructed after May 1999, using wind resistant technology have been well received by the market.
- Home Creations reports that roughly 50% of their growth since May 1999 is due to the marketing of wind resistant features.
  - Anchor Bolts
  - Roof anchors
  - Enhanced exterior sheathing.

Tornado Mitigation Market Analysis

- Some builders in OKC and Tulsa have begun installing saferooms/multi-purpose rooms. (Greenway Group)
- Retrofit shelters as % of Building Permits

1999-2002

OKC	Moore	Midwest City	Norman
22.1%	39.9%	68.4%	10.0%

Tornado Mitigation Market Analysis

- University of Oklahoma and Austin College
  - Using 2005 MLS data and tornado shelter inventory we can estimate the effect of tornado mitigation on resale price
  - Funded by ICLR
- Austin College
  - Analysis of the household attributes which make purchase of mitigation more likely
  - Funded by ICLR

Tornado Mitigation Policy Analysis

- Oklahoma Saferoom Initiative.
  - Initial program was oversubscribed.
  - Local programs in Ada and Lawton.
  - Newest statewide program (2004).
  - Applications increased in counties with higher historical tornado frequency.
- SQ 696 – Tax Incentive for Saferooms.

WSR-88D, Tornado Warnings and Tornado Casualties

- This study examines the effect doppler radar has had on injuries and fatalities.
- Study runs from 1986 – 2002. 18,000 storms are included in the analysis.

Project Funding

- Department of Commerce – NOAA
  - National Severe Storms Laboratory

Research Questions

- Percentage of tornadoes which received a warning.
- Effect on warning lead time.
- Effect on Casualties
  - Fatalities
  - Injuries

Jarrell, TX Tornado 27 May 97 2032Z
Tornado at photo time (3:32 pm CDT) is about 1 mi N of Jarrell, headed into town, as documented by storm chaser Lon Curtis. Image used by permission.

Data Sources

- Storm Prediction Center National Tornado Archive (1950-1999)
- Radar Operations Center – Radar Installation/Commissioning Dates
- NOAA – tornado warning verification statistics (Beg. 1/1/1986)
- Census Data – economic and demographic characteristics

Study Parameters

- Database includes all tornadoes in the U.S. between 1986 and 2002.
- Approximately 18,000 tornadoes.
- County level census data from the 1980, 1990 and 2000 census.

Study Variables

- Doppler – 1 if Doppler radar was installed, 0 otherwise.
- F-Scale – Dummy Variables for each category in the Fujita Scale, F0 omitted.
- Density – County population per square mile.
- Income – County average family income.
- Mobile – percentage of mobile homes in the county.
- Length – track length in tenths of miles.

Study Variables

- Season – 1 for March, April, May, June, 0 otherwise.
- Day/Evening – Day from 6:00 a.m. to 5:59 p.m., Evening from 6:00 p.m. to 11:59 p.m. Night omitted.
- Year – Dummy variables for each year, 1986 omitted.

Doppler Radar & Tornado Warnings by F-Scale

		Percentage of Tornadoes Warned for		Mean Lead Time in Minutes	
F-Scale Category	F-Scale Category	Before Doppler	After Doppler	Before Doppler	After Doppler
0	0	33.6%	58.6%	5.18	9.45
1	1	33.0%	56.4%	5.04	8.77
2	2	40.0%	68.4%	5.54	10.90
3	3	54.8%	86.7%	7.60	13.90
4	4	64.2%	93.5%	8.61	

Effect on Casualties

- When simple averages are used, casualties increase after full implementation of Doppler Radar.
  - 1986-1996 Avg. Annual Fatalities=39.5
  - 1997-1999 Avg. Annual Fatalities=97.3
  - 1986-1996 Avg. Annual Injuries=946
  - 1997-1999 Avg. Annual Injuries=1578

Effect on Casualties

- Simple averages fail to account for important variables that could increase or decrease casualties.
- Regression models are used to control for the important determinants of casualties such as the size of the tornado etc.

Regression Model

- Poisson Model
  - Nature of observations is count data with a large number of zeros for the dependent variable.
  - This model is commonly used to estimate mortality rates in the medical field.
  - One important assumption of this model is equality of the conditional mean and variance of the dependent variable. Violation of this assumption is known as overdispersion.

Generalized Model

- Fatalities/Injuries = f(Doppler, F-Scale, Density, Income, Mobile, Length, Length*Density, Season, Day, Evening, Year)

Results
Injury Model

- Injuries
  - Doppler Radar reduces injuries by 40%.
    - 95% confidence interval: 16% - 57%.
- Other Significant Variables
  - Mobile Homes (If mobile homes increase by 1%, injuries are expected to increase 5%).
  - Expected injuries from day tornadoes are 47% lower than tornadoes at night.
  - Expected injuries from evening tornadoes are 43% lower than tornadoes at night.

Results
Fatality Model

- Fatalities
  - Doppler Radar reduces fatalities by 45%.
    - 95 % confidence interval: 20% - 63%.
- Other Significant Variables
  - Mobile Homes (If mobile homes increase by 1%, fatalities are expected to increase by 6%)
  - Day tornadoes are 66% less deadly than tornadoes at night.
  - Evening tornadoes are 45% less deadly than tornadoes at night.

Model Inferences

- Since 1997, tornado fatalities have averaged 68.1 deaths per year.
- Based on our findings, we can infer that Doppler Radar avoided 56 tornado fatalities per year.

Conclusion

- Based on our analysis, which focused on the effect of Doppler Radar installation, both fatalities and injuries have been significantly reduced.

Ongoing Research

- Funding: Dept. of Commerce – NOAA
  - Database expansion beyond 1999 will allow for analysis of other NWS programs such as the StormReady program.
  - With the potential of Phased Array Radar, our model can examine incremental effects on casualties if warning lead time is increased.
- Funding: Quick Response Grant – Natural Hazards Research Center
  - "You Can Run or You Can Hide: Sheltering Decisions in a Tornado"

Ongoing Research

- Using additional data on False Alarm Rates, we can estimate the effect Doppler has had on the quality of warnings.
- Using accepted estimates of value of life and avoided injuries, we can perform a cost/benefit analysis of the Doppler program.

Tornado Mitigation

- Simmons and Sutter (Forthcoming), *Risk Analysis*.
- Simmons and Sutter (Forthcoming), *Midwestern Business and Economic Review*.
- Simmons and Sutter (2005), *Weather and Forecasting*.
- Simmons and Sutter (2005), *Land Economics.*
- Simmons and Sutter (2005), *Natural Hazards Review*.
- Merrill, Simmons, Sutter (2002), *Weather and Forecasting*.
- Merrill, Simmons, Sutter (2002), *Journal of Economics*.

Mitigation: From the Ivory Tower to the Real World

- Does regulation work?
  - Clearly enhanced building codes provided better protection from Hurricane Charley.
  - The challenge is gaining the support of builders and the ultimate consumers of coastal properties.

Mitigation: From the Ivory Tower to the Real World

- Do better warnings work?
  - Evidence from our Doppler radar study suggests that improvements in technology does indeed save lives and avoids injuries.
- Are warnings cost effective?
  - Our estimates indicate that the investment in Doppler radar easily justifies the cost by the number of avoided fatalities and avoided injuries

Mitigation: From the Ivory Tower to the Real World

- Do markets for mitigation work?
  - Consumers must perceive a risk before behavior changes.
- Key for consumers will be consistent information from a variety of sources:
  - Government
  - Insurance Companies
  - Suppliers
  - Universities

Mitigation: From the Ivory Tower to the Real World

- Consumer interest is highest in the aftermath of an event.
- Acceptance of mitigation can be extended beyond the immediate event reaction.
  - Message about the need for mitigation must be consistent from all sources.
  - Should not be a "New" message.
  - Message should continue, even beyond the immediate period following a storm.

Mitigation: From the Ivory Tower to the Real World

- When consumers see government, industry and academia working as partners, information concerning mitigation becomes more credible.

Undergraduate Research at Austin College

- AC Weather Station
- Social Science Research Lab
  - 2004 Florida Hurricanes
  - Saferoom Survey
    - Funded with NIST funds through Texas Tech
    - ICLR Funding
    - Mellon Foundation

Ending with A Pleasant Weather Phenomenon

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