Journal Pre-proof

Effects of Roof Age on Asphalt Shingle Performance During High Wind Events

Wesam M. Mohamed, Rachel N. Kovar, Franklin T. Lombardo, Tanya M. Brown-Giammanco

PII: S2352-7102(26)01822-X

DOI: https://doi.org/10.1016/j.jobe.2026.117000

Reference: JOBE 117000

To appear in: *Journal of Building Engineering*

Received Date: 23 January 2026

Revised Date: 20 July 2026

Accepted Date: 27 July 2026

Please cite this article as: W.M. Mohamed, R.N. Kovar, F.T. Lombardo, T.M. Brown-Giammanco, Effects of Roof Age on Asphalt Shingle Performance During High Wind Events, *Journal of Building Engineering*, https://doi.org/10.1016/j.jobe.2026.117000.

Effects of Roof Age on Asphalt Shingle Performance During High Wind Events

Wesam M. Mohamed[1,*], Rachel N. Kovar[1], Franklin T. Lombardo[1], Tanya M. Brown-Giammanco[2]

[1] University of Illinois Urbana-Champaign, Urbana, 61801, Illinois, USA

[2] National Institute of Standards and Technology, 20899, Gaithersburg, MD, USA

* Corresponding author. Department of Civil and Environmental Engineering, University of Illinois Urbana-Champaign, Illinois, USA, E-mail address: wesammm2@illinois.edu

Abstract

This manuscript aims to examine whether roof age affects the level of roof cover damage observed under relatively similar hurricane wind speeds. This manuscript reports the results of an observational study of damaged asphalt roof shingles after Hurricane Laura in 2020. Damage to roof covers was subjectively estimated in percentage ranges through the use of post-hurricane aerial imagery, while roof age was estimated using roof cover damage from Hurricane Rita in 2005 or the year built after 2005, using readily available online databases. Results show that age is a clear factor in the level of roof cover damage for areas of similar peak wind speeds obtained from estimates of the wind field (i.e., H*Wind). A 'break' in age is found to occur centered around the 8-year mark, where damage notably increases. However, this value should be interpreted as an empirical breakpoint in this dataset rather than a general threshold. Investigating other factors, such as roof shape, shows relationships with age as well, including older hip roofs sustaining notably more damage than the gable or complex (i.e., combination of features) roofs of the same age. These findings provide field data as evidence of the effects of roof age and highlight the need for future studies to isolate roof age from other factors such as construction quality, maintenance history, geometry, exposure, and other confounding factors.

Keywords

Roof damage, Hurricane Laura, Asphalt shingles, Wind performance, Roof aging

Highlights

- An observational analysis of 623 asphalt shingle roofs damaged during Hurricane Laura (2020) shows an association between roof age and damage severity.
- Roofs older than eight years exhibited a notable increase in observed damage levels compared to roofs less than eight years, with 97% of 14–15-year-old roofs within the analyzed sample experiencing some level of failure.
- Hip roofs were more susceptible to roof cover damage with an increase in roof age than gable roofs, especially for roof ages 8 years and older.

1. Introduction

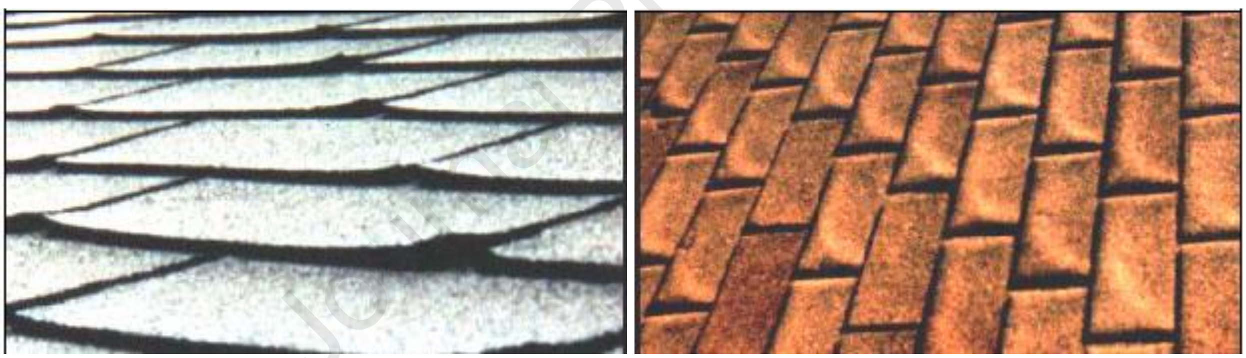
Asphalt shingles are the most popular roof cover type for residential construction in the U.S. [1,2]. Materials, attachment methods, and associated test standards for asphalt shingles have evolved over the years [3]. Damage to asphalt shingles and other roof cover types is a common occurrence after high wind events [2,4,5,6,7,8,9,10,11] despite test standards such as ASTM D7158, which approves new shingles for up to 86 m/s (194 mph) wind [12].

The performance of a roof cover during a high wind event can be greatly influenced by various characteristics of the building and the roof itself, including the roof shape, the number of stories, the relative orientation of the home with respect to the wind direction, material properties, construction quality and maintenance/repairs. It can also be affected by location-specific features, such as nearby obstructions. In addition, a key factor that likely contributes to the amount of damage is the age of the roof [2].

The wind resistance of an asphalt shingle roof is linked directly to the performance of the sealant, meaning a shingle roof is more vulnerable to wind damage when the shingles become unsealed. In practice, shingles are subjected to weathering over time, which can result in blistering and deterioration of the shingles and their sealants. Cupping and clawing can occur due to shrinkage at the edges of the shingles, which is often a result of excessive heat. Cupping in asphalt shingles, as shown in Figure 1(a), refers to the upward curling of the corners and edges of asphalt shingles. Cupping results from asphalt shrinkage on the top surface of the shingle, causing the mat to contract and the edges to lift [13]. Clawing, as shown in Figure 1(b), is the opposite phenomenon, where the center portion of the shingle pulls downward while the edges remain relatively flat. It results from asphalt shrinkage on the bottom surface of the shingles, which draws the shingle downward toward the roof deck [13]. The older a roof is, the longer it has been subjected to these conditions. In a study conducted on Texas and Florida homes, Dixon et al. [2] found that asphalt shingle roofs appeared to remain sealed for the first four or five years of their service life, but beyond that, an increase in the number of unsealed shingles was observed. Despite this, performance test standards of shingles, such as ASTM D7158 (2024) [12], ASTM D3161 (2025) [15], and ASTM D6381 (2024b) [16] use new, fully sealed shingles, and long-term weathering and changes are not accounted for. In the field, determining the age of a roof is difficult, especially for older buildings, since a roof replacement may have occurred, and this is not typically captured in real estate records, and many jurisdictions do not require a building permit.

Hurricane Rita in 2005 and Hurricane Laura in 2020 affected nearly the same regions of Louisiana. Their proximity allowed an assumption that any roofs with notable damage (i.e., 25% roof cover damage or greater) from Hurricane Rita were fully replaced in 2005 or early 2006, making them approximately 15 years old at the time of Hurricane Laura. While just an assumption, this is a valuable improvement over previous studies [2,9,10], which had to rely only on building age as a proxy for roof age, because building age is much easier to determine from public records and real estate databases. This assumption becomes increasingly problematic for the older homes assessed in previous studies. Hurricane Laura provided an opportunity to evaluate the effect of wind damage on assumed 15-year-old shingle roofs with high confidence. For homes built between Hurricanes Rita and Laura, the assumption was that roof age was equal to the age of the building. It is worth noting that the Lake Charles office of the National Weather Service documented a historic severe thunderstorm on June 4, 2007, that produced golf-ball-size hail, peak gusts of approximately 33 m/s, and reported damage in the Lake Charles area [17]. Significant damage to roofs due to hail was not reported. The 33 m/s wind gust was the highest recorded official gust in the area over the 15-year period of study, which is lower than the maximum wind gusts analyzed in this paper. In addition, no tornado damage paths affected the study area over the 15-year period [18]. While some roof covers may have been replaced following the 2007 event, the magnitude of the event, the lack of other notable events over the period of study, and the number of roofs assessed make it generally reasonable to assume roof ages as described above.

Since 2005, Louisiana has utilized the International Code Council's (ICC) building codes with state-specific amendments. For residential construction, which is the focus of this study, Louisiana is covered by the International Residential Code (IRC). There were very few roof covering-related changes to the building code over the period of this study. Prior to 2009, the IRC [19] stipulated that asphalt shingles had to be rated to ASTM D3161, while after 2009 the IRC [20] also allowed shingles rated to ASTM D7158. These standards experienced some changes as well, described later in Section 3.2.2. The specific classes of shingles allowed under these ASTM standards were dependent upon the design wind speed of the location of use as specified in the IRC.



(a) (b)

Figure 1. *(a) Example of cupping in asphalt shingles. (b)Example of clawing in asphalt shingles. [13]*

Roof cover damage levels were assessed through aerial imagery for the homes affected by both Rita and Laura, or Laura only (homes built after 2005). Levels of roof cover damage in Hurricane Laura were compared to the assumed age of the roof. In addition to single-factor roof age analyses, analyses were performed to compare the relationships between roof age, level of roof cover damage, and other home characteristics such as the roof shape and the peak wind speed. The main research questions addressed within this manuscript are: (1) Is there a relationship between roof cover age and the level of damage observed in asphalt shingle roof covers after Hurricane Laura within the selected Louisiana study areas? (2) Do roof shape and range of wind speeds change the observed relationship between roof cover age and damage severity? The working hypothesis is that older asphalt shingle roof covers exhibit higher levels of visible damage because weathering can reduce sealant performance and increase the probability of shingle unsealing, which is based on previous findings from [2,3,9,10]. The analysis in this manuscript sought to confirm and quantify these associations and is not intended to imply that roof age alone caused the observed damage. This manuscript is based on an observational study after hurricane events rather than a controlled experiment.

2. Datasets and Methods

To conduct this study, two distinct areas of homes with a relatively high density of properties to provide large data quantities were selected. These distinct areas were homes on the immediate coastline (i.e., coastal) in the Holly Beach, LA area and ones further inland (i.e., inland homes) near Lake Charles, LA. Specifics of these homes and their characteristics are outlined in this section.

2.1 Roof Cover Age and Home Characteristics

The first step in assessing roof cover age involved utilizing post-Hurricane Rita NOAA aerial imagery [21] to identify homes that had suffered roof cover damage within the study areas. The roof cover damage was visually estimated for each home following the methodology of [11]. To limit the potential for errors within the dataset, homes that exhibited less than 25% roof cover damage from Hurricane Rita were not considered for the study, as it was possible that either a roof replacement or a roof repair had not occurred. Homes that incurred an estimated 25% roof cover damage or greater from Hurricane Rita were assumed to have received a full roof replacement, meaning they were assumed to have an approximate roof age of 15 years at the time of Hurricane Laura in 2020.

The second step in assessing roof age was utilizing the online real estate database, Zillow, to identify homes within the study area that were built between the years 2005 and 2020. These homes were assumed to have no roof cover replacement between the time of construction and Hurricane Laura; thus, the roof cover age of each home was assumed to be the same as the home itself. This assumption provided a sample of homes with estimated roof cover ages from 0-15 years at the time of Hurricane Laura's landfall. For each home evaluated with this method, the address was obtained from Zillow, which allowed it to be identified in the aerial imagery and used for damage assessment.

Based on the two described steps and within the study area, 634 homes (538 suburban and 96 coastal) were available for analysis. For certain roof ages, there was a relatively low number of buildings, as shown in Figure 2. Thus, roof ages were binned into two-year bins as shown in Figure 3 to reduce limitations and allow for further analyses. As can be seen, the zero and one-year roof age bins have limited data and thus were excluded from the analyses where specified, resulting in a sample size of 623 homes.

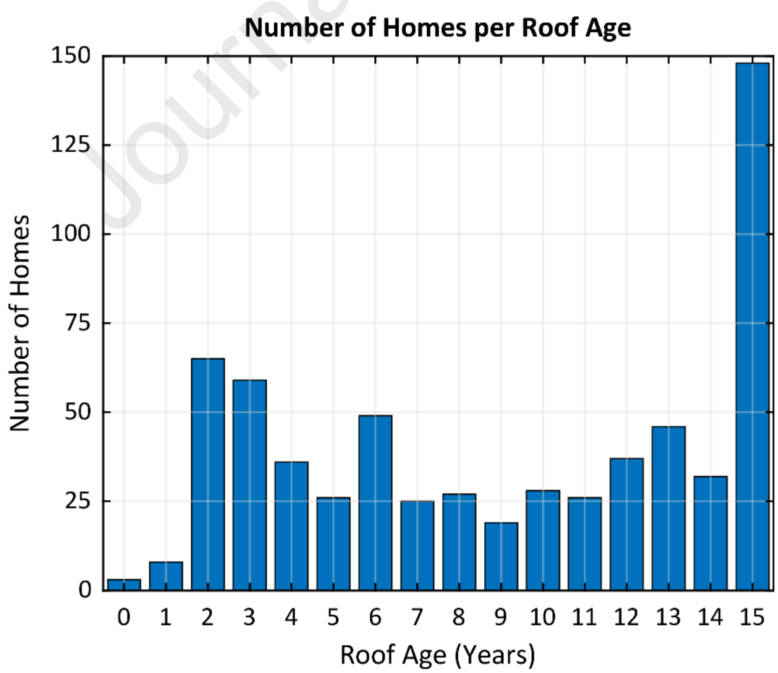


Figure 2. *Number of homes per roof age.*

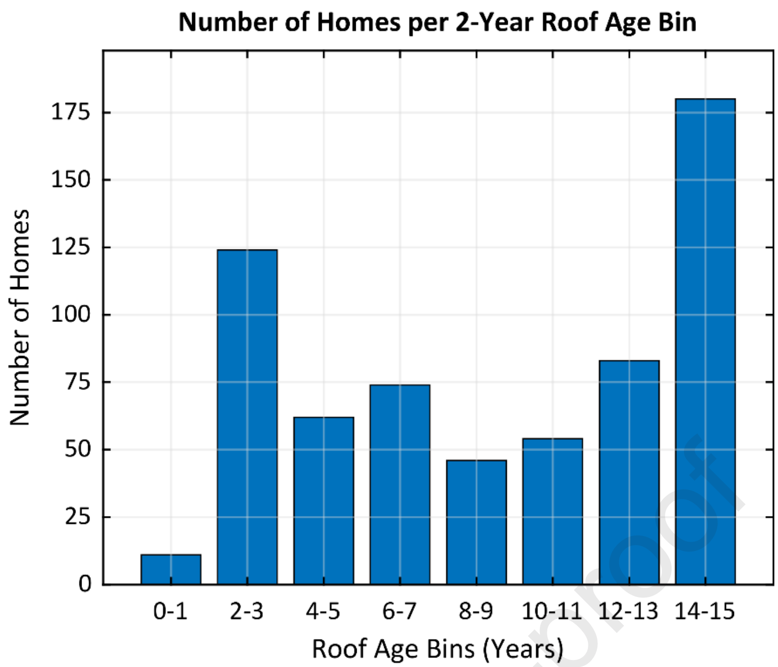


Figure 3. *Number of homes per 2-year roof age bin.*

For all homes, the roof shape was determined from Zillow and aerial imagery and was categorized as hip, gable, or complex. The hip category consisted of homes with simple hip and hip and valley type roofs; the gable roofs were separated in the same manner. Within the complex roof category are the homes with both hip and gable features, as well as unique characteristics such as dormers and multi-level roofs. Figures 4(a) and 4(b) are representative of hip roofs, Figures 4(c) and 4(d) are representative of gable roofs, and Figures 4(e) and 4(f) are representative of complex roofs.

Figure 4. *Examples of each roof shape. (a) and (b) are hip roofs, (c) and (d) are gable roofs, and (e) and (f) are complex roofs. Imagery obtained from NOAA.*

2.2 Wind Speed and Direction

Following the methodology of [23] in assessing garage door performance, aerial imagery was paired with the gridded wind speed and direction data for Hurricane Laura, which were obtained from RMS's H*Wind product [24]. The H*Wind 3-s gust wind speed data in open terrain were converted into an ArcGIS shape file to evaluate the relative peak wind speed at the grid locations. The closest H*Wind data points were used to estimate the peak wind speed at each home location, as well as the approximate wind direction at the time of the peak wind speed. The homes included in this study were located in areas of peak wind speed 55 m/s – 59 m/s (123 mph - 132 mph) in the inland (i.e., suburban) areas and 62 m/s – 67 m/s (140mph - 149 mph) peak wind speed in the coastal areas. Figure 5 shows the location of all 623 homes assessed in the study with the wind speed estimate from H*Wind overlaid.

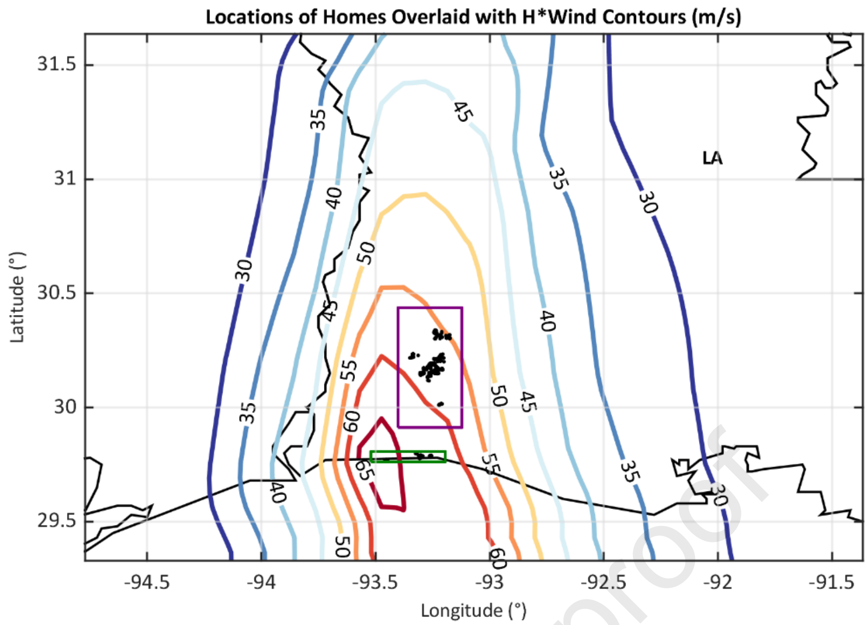


Figure 5. *Map showing locations (black dots) of homes included within the dataset overlaid with H*Wind contours (in m/s). The coastal region of the study is included in the green rectangle at the bottom of the image, while the inland area is included in the purple rectangle.*

2.3 Damage Estimation (Hurricane Laura)

The level of roof cover damage caused by Hurricane Laura was visually estimated for each home using the post-Hurricane Laura NOAA aerial imagery [22] following the methodology of [11]. Each home was classified with one of five roof cover damage severities: no damage, $\leq$25% damaged, >25-50% damaged, >50-75% damaged, or >75% damaged. Examples of the damage categories (not including the 'no damage' category) are provided in Figure 6. The 25% interval in damage levels was used because it is consistent with the damage level approach used in previous remote sensing wind-damage studies [11,23,27] and because aerial imagery can support reliable classification into damage ranges rather than precise percentage estimates. The levels provide a repeatable visual scale for comparing relative roof cover damage severity across a large post-hurricane damage dataset.

Figure 6. Examples of each roof cover damage state. From left to right: ≤25% damaged, >25-50% damaged, >50-75% damaged, >75% damaged. Imagery obtained from NOAA aerial imagery.

3 Hurricane Laura Damage Analysis and Results

3.1 Roof Age Analysis

A database was developed to record the location, roof cover age, estimated peak wind speed, and roof cover damage severity category, to allow for analysis. An example of roof cover damage by age in the coastal region of the dataset is shown in Figure 7, which illustrates the relative increase in visible roof cover damage with increasing roof cover age across an area with similar wind speeds. The percentages of homes in each roof age bin for a given roof cover damage level are shown in Table 1 and for homes with roofs older than one year in Figure 8 which includes all homes in the study.

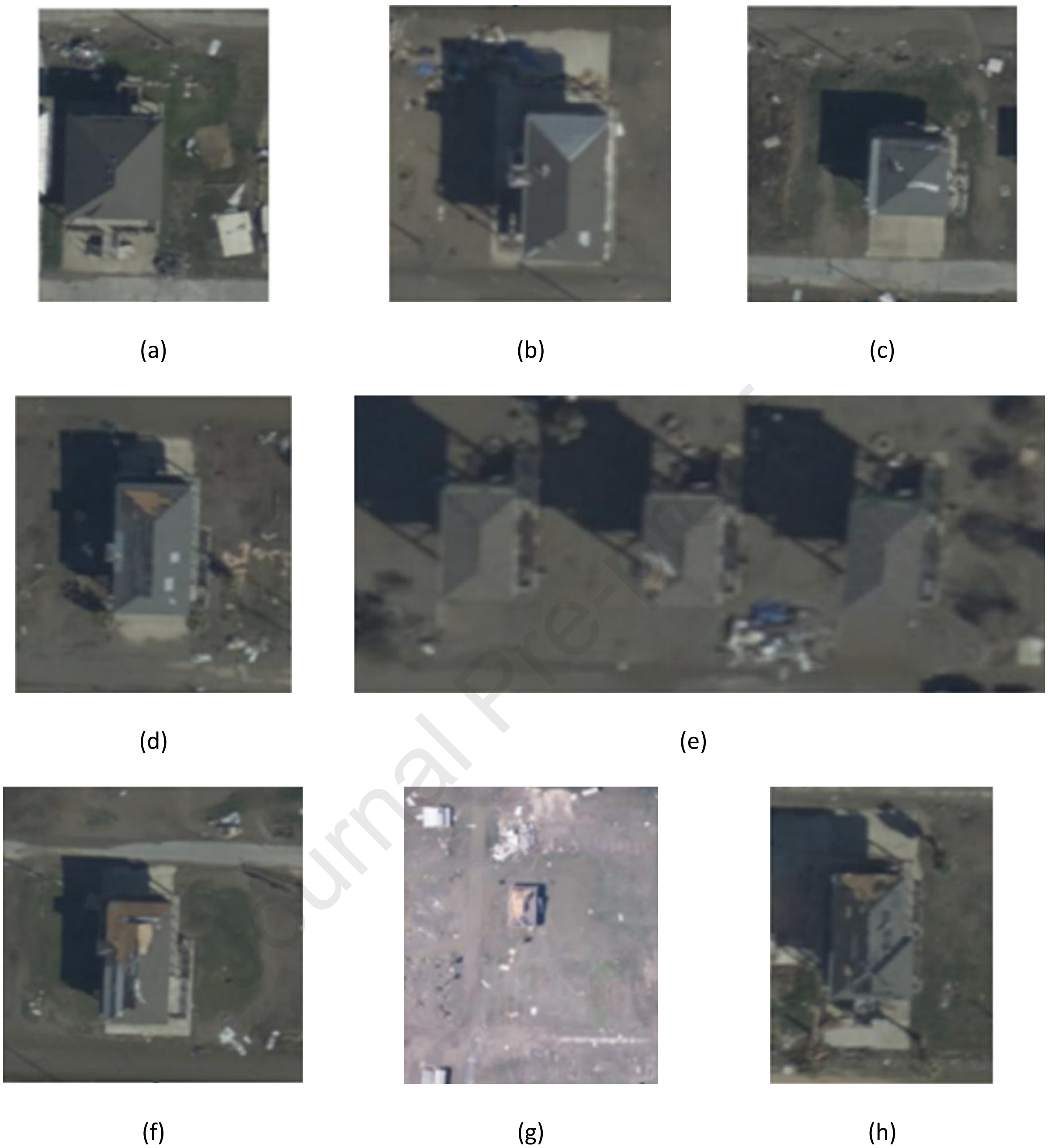


Figure 7. *Examples of each roof cover damage state by roof age for homes in close proximity in Holly Beach, LA (coastal region). (a) Roof age: 2 years, (b) Roof age: 3 years, (c) Roof age: 5 years, (d) and (e) Roof age: 8 years, (f) Roof age: 10 years, (g) and (h) Roof age: 11 years.*

Table 1. All Homes (Roof Coverings) Assessed in this Study.

Age Bin	Number of homes	Homes with no damage (n)	Homes with no damage (%)	Homes with <25% damage (n)	Homes with <25% damage (%)	Homes with 25-50% damage (n)	Homes with 25-50% damage (%)	Homes with 50-75% damage (n)	Homes with 50-75% damage (%)	Homes with >75% damage (n)	Homes with >75% damage (%)
2-3	124	74	60	41	33	5	4	1	1	3	2
4-5	62	21	34	31	50	6	10	2	3	2	3
6-7	74	28	38	38	52	3	4	4	5	1	1
8-9	46	16	35	19	41	9	20	0	0	2	4
10-11	54	3	6	24	44	17	31	8	15	2	4
12-13	83	8	10	34	41	15	18	18	21	8	10
14-15	180	5	3	65	36	42	23	36	20	32	18
Total	623	155		252		97		69		50	

Figure 8 shows that the performance of newer roof covers was better than that of older roof covers. For example, the majority (60%) of 2-3 year roofs exhibited no roof cover damage, while only 3% of 14-15 year old roof covers exhibited no damage. As another example, for the highest damage levels, only 2% of 2-3 year old roof covers had > 75% damage, while the percentage was 18% for 14-15 year old roof covers.

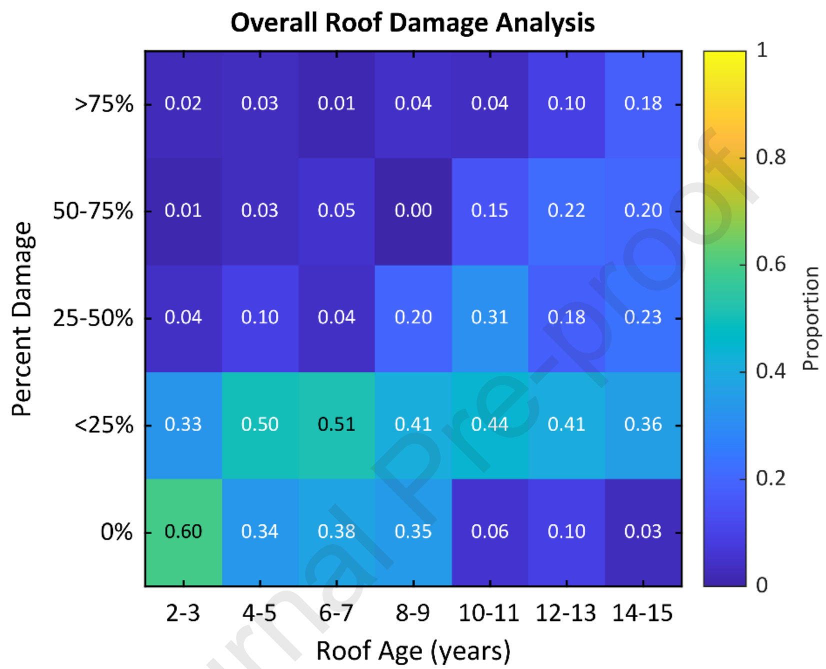


Figure 8. *Proportion of homes per roof age bin for a given roof cover damage level.*

Figure 9 provides another way to view the damage data, which shows the cumulative percentage of homes that experienced a minimum roof cover damage level. For example, in the 2-3 year age bin, 40% of all homes within that age bin had at least some roof cover damage (>0%), 7% of the homes experienced at least 25% roof cover damage, 3% of homes experienced at least 50% roof cover damage, and 2% experienced at least 75% roof cover damage. As the roof age increased, the percentage of homes with at least some roof cover damage (>0%) generally increased, to the point where 97% of homes 14-15 years old exhibited some damage to the roof cover. In general, the older the roof cover age, the higher the likelihood of damage at each increasing cumulative damage level.

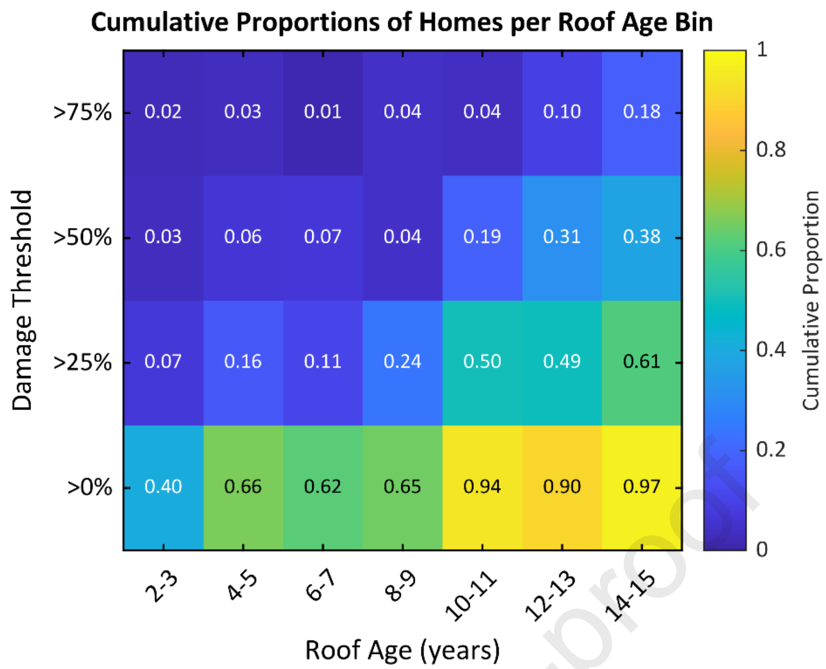


Figure 9. *Cumulative proportions of homes per roof age bin for a given roof cover damage level (no undamaged homes included).*

Figure 10 uses the same data as Figure 8 and plots the proportion of homes in each damage category for each roof age bin. Illustrated this way, it becomes even clearer that age is a factor in the level of roof cover damage. The proportion of roof covers experiencing "no damage" drops off considerably between the 8-9 and 10-11 year bins. For specific damage levels, especially above the < 25% level, the proportion of homes within those damage levels increased for certain age bins. For example, the age at which roof covers experienced a notable increase in the 25-50% damage level is between the 6-7 and 10-11 year bins, while the age at which they experience a notable increase in the 50-75% damage level is between the 8-9 and 12-13 year age bins. The age at which they experience an increase in the >75% damage level is between the 10-11 and 14-15 year age bins. As an example, a home is over five times more likely on average to have 25-50% roof damage for the range of wind speeds considered if the roof cover is 10-11 years old versus 6-7 years old. The age transition noted between the 8-9 and 10-11 year-old bins is specific to the analyzed dataset representing the change in the observed damage levels in Hurricane Laura rather than an experimentally verified threshold for asphalt-shingle deterioration.

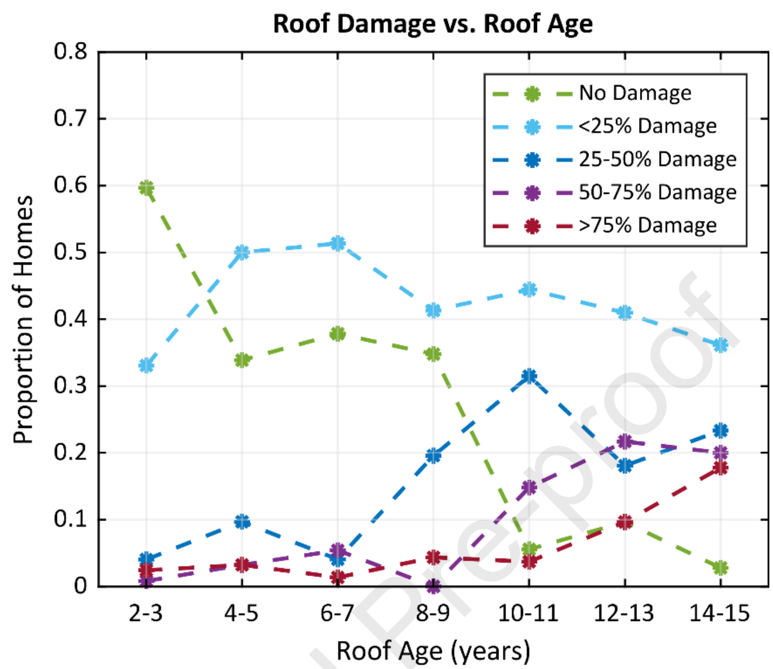


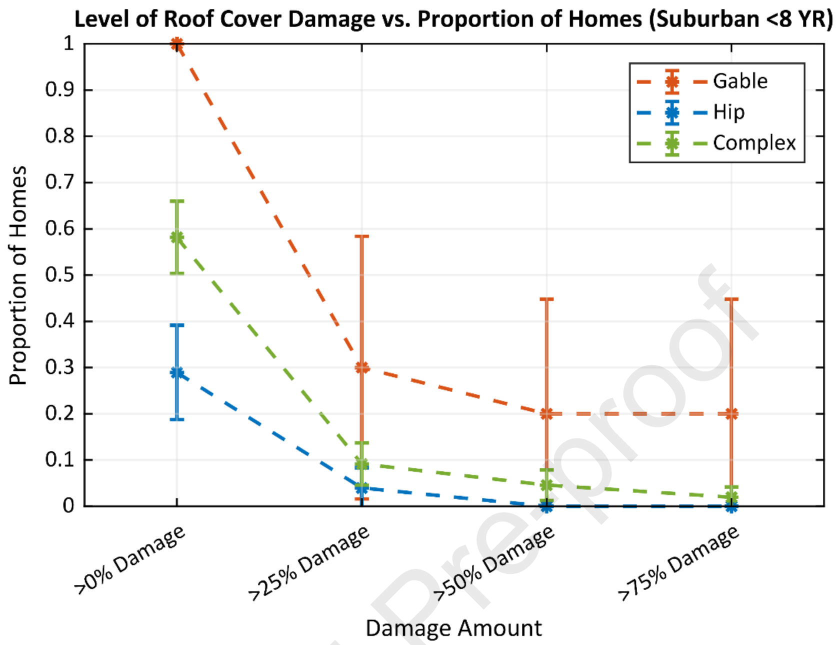
Figure 10. *Proportion of homes with various roof cover damage levels by age bin.*

3.2 Home Characteristics Analysis

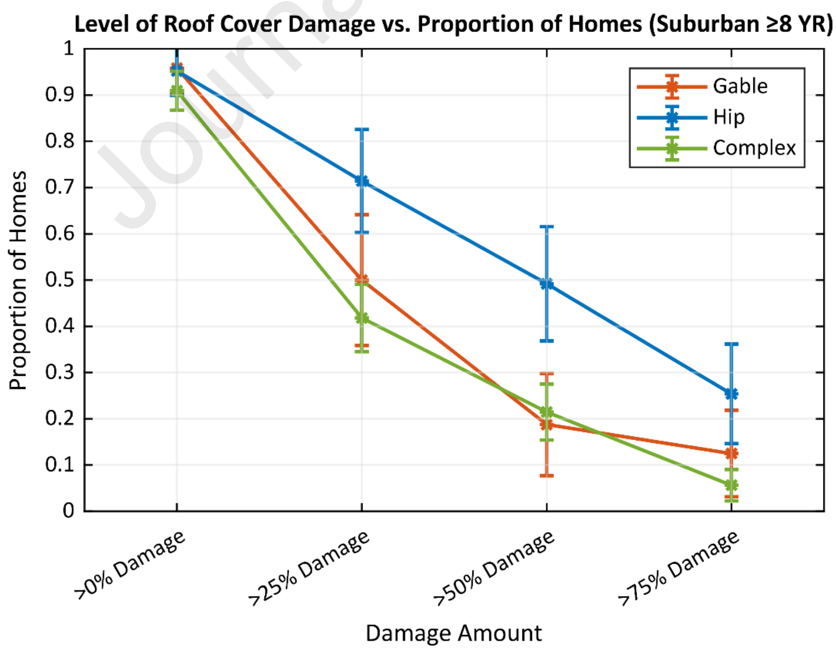
To elaborate on the findings in Section 3.1, which purports age as a key factor affecting roof cover performance, the next part of the analysis included additional home characteristics such as roof shape. To provide additional clarity on the results, **only the homes/roofs in the suburban areas** were used in the analysis. The rationale behind using the suburban roofs is twofold. First, the overwhelming majority (527/623 ≈ 85%) of analyzed roofs (ages ≥ 2 years) are within these regions, maintaining a large sample size. Secondly, it should significantly reduce the effects of peak wind speed on damage (which is likely to be a significant predictor of damage) as the H*Wind-derived peak wind speeds ranged from approximately 55 m/s – 59 m/s (123 mph - 132 mph) in the inland regions. Similarly, it avoids adding uncertainty if modifying the H*Wind speeds to a terrain and roof height in line with actual conditions, which would be considerably different for inland vs. coastal exposure, further increasing wind speed differences. To further increase sample size and produce additional clarity in findings from Section 3.1, larger age bins are also utilized in this section, where noted.

3.2.1 Roof Shape

Additional analyses were carried out to evaluate the effect of roof shape on roof cover performance. Roof shapes considered are hip, gable, and complex, as discussed in Section 2. Roof covers were first grouped into two large age bins: less than 8 years old and greater than or equal to 8 years old. The results are presented in Figure 11, which illustrates that newer (i.e., < 8 years) gable roofs experienced roof cover damage at a higher frequency than newer hip and complex roofs. The proportion of gable roofs in each roof cover damage level category is similar regardless of age, while for hip and complex roofs, the difference in roof cover damage levels with age is notable, where older roof covers (>= 8 years) are damaged at a higher frequency than newer roof covers (< 8 years). Older (>= 8 years) gable and complex roofs have a similar frequency of homes at each roof cover damage level, while older (>= 8 years) hip roofs display higher frequencies of homes at nearly all roof cover damage levels in comparison. This result is contrary to previous studies, which have shown that gable roofs generally experience higher levels of damage than hip roofs [26,27,28]. Dixon et al. [2] noted that shingles on the hips themselves (the intersection of different roof faces) were more susceptible to unsealing than those located in the field of the roof and were therefore more likely to be damaged during high wind events. Newer hip roofs followed the findings of previous studies, with a lower frequency of damaged homes than gable roofs. Assuming that the likelihood of damage level is binomially distributed, plus and minus one standard error is also plotted for each of the damage levels in Fig. 11. The error bars demonstrate higher uncertainty in the proportion of gable roof damage less than 8 years old especially for higher damage states, however, the conclusion that gable roofs suffer damage in higher proportions is generally accepted throughout the literature. For roofs greater than or equal to 8 years of age, the conclusion of greater proportions of hip roofs damaged holds weight as there is little or no overlap between the possible ranges of hip and gable roof damage, especially for moderate damage levels (50% damage and less).



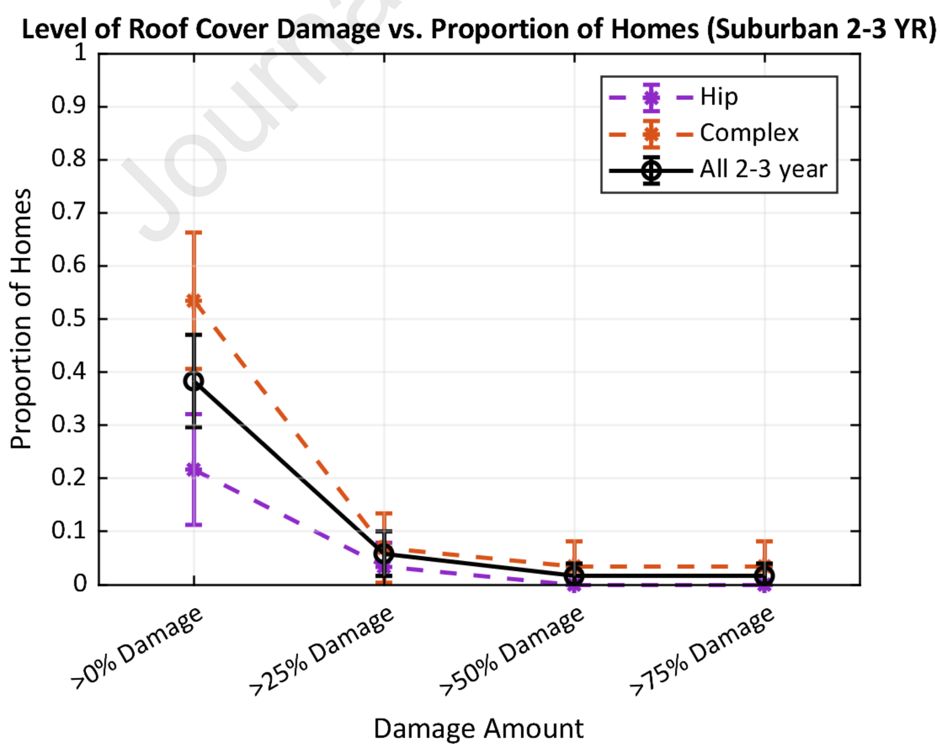
(a)



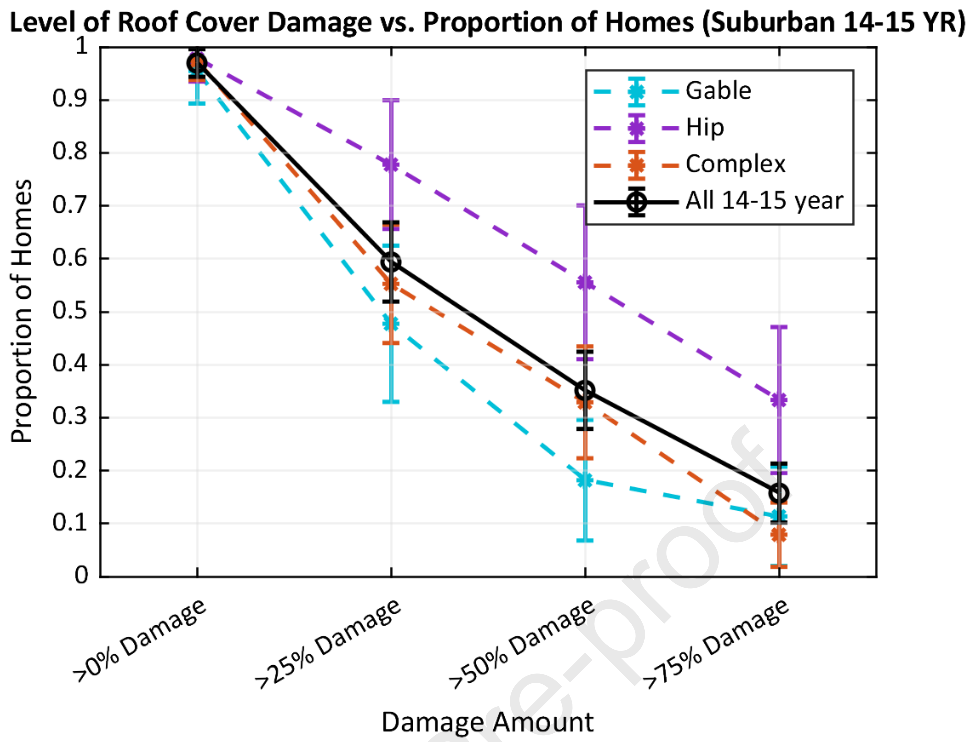
(b)

Figure 11. *Roof cover damage by roof shape for newer and older roofs.* ***(a)****less than 8-year-old roofs and* ***(b)*** *greater than or equal to 8-year-old roofs.*

To further illustrate the effects of both age and roof shape, Figure 12 plots proportions of cumulative damage levels for 2-3 year old roofs and 14-15 year old roofs – the newest and oldest age bins in the study – with different roof shapes. Figure 12a shows that age alone is not the only factor affecting the presence of roof cover damage, as complex roofs had a much higher frequency of homes in the lowest damage level (> 0%) than hip roofs. By contrast, once roof cover damage exceeds 25%, the roof shape does not notably affect the frequency of 2-3 year old roof covers in each damage bin. The opposite is observed in Figure 12b, where nearly all 14-15-year-old roof covers, regardless of shape, have at least minimal roof cover damage (> 0%). For these older roofs, there does appear to be performance differences at the higher levels of damage (> 25%) for different roof shapes, which echoes the findings illustrated in Fig. 11. Assuming that the likelihood of damage level is binomially distributed, plus and minus one standard error is also plotted for each of the damage level in Fig. 12. The results further strengthen the claim of differences by roof type in the older roofs, as there is little or no overlap in the error bounds.



(a)



(b)

Figure 12. *Roof cover damage by roof shape for **(a)** 2-3 year old roofs and **(b)** 14-15 year old roofs.*

3.2.2 Wind Speed

Roughly the same wind speed (10 m, 3-s gust) was encountered by all the inland roofs included in this study during Hurricane Laura, so the analysis described in the previous sections is independent of wind speed. However, Hurricane Rita had peak wind speeds much lower than Hurricane Laura for the areas evaluated in this study, so a comparison was conducted to evaluate the effect of wind speed for the subset of homes that suffered roof cover damage in both hurricanes. Wind speeds were extracted from H*Wind for both events. The roof cover performance comparison is highlighted in Figure 13. For all cumulative roof cover damage levels (e.g., > 25% damage), the proportion of homes in Rita was much higher than in Laura, even though the maximum wind speeds were lower. For example, in Hurricane Rita, in the >25% damage category, a roof cover was almost twice as likely to be damaged in 40 m/s – 45 m/s (90 mph - 100 mph) in Hurricane Rita versus 55 m/s – 60 m/s (123 mph - 134 mph) in Hurricane Laura. This difference suggests that shingles in place during Hurricane Laura were better able to withstand extreme winds than those in place at the time of Hurricane Rita.

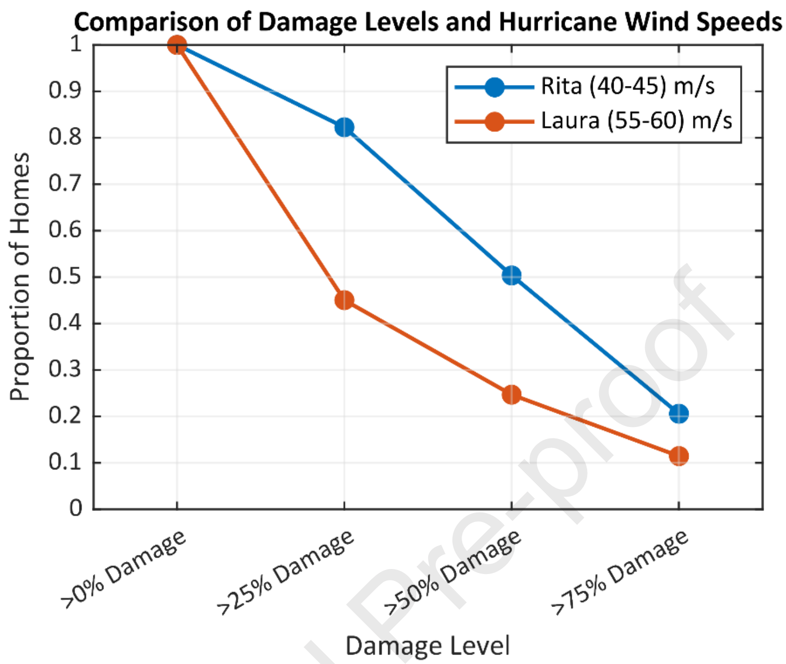


Figure 13. *Proportion of homes with various cumulative roof cover damage levels given wind speed ranges for Hurricanes Rita and Laura.*

It should be noted that shingles that were in place at the time of Hurricane Rita would primarily have been rated to ASTM D3161. The 1999 version of ASTM D3161 [29], as well as earlier versions, tested shingles up to 27 m/s (60 mph), but when the 2003 version of ASTM D3161 [30] was published, the range of test speeds was from 27 m/s – 49 m/s (60 mph - 110 mph), a range which continues today (ASTM 2025) [15]. It is unlikely that many of the shingles installed prior to Hurricane Rita would have been rated to 49 m/s (110 mph), given the small amount of time between the publication of the 2003 version of ASTM D3161 [30] and Hurricane Rita in 2005. ASTM D7158 [31] was not published until 2005, and it is unlikely many manufacturers would have begun manufacturing and testing to this new standard in time for these shingles to have been installed in large numbers prior to Rita's landfall. ASTM D7158 had a maximum wind speed rating of 67 m/s (150 mph) when first published [31] and was raised to 85 m/s (190 mph) in 2016

[14] before increasing again to 87 m/s (194 mph) in the 2024 version [12]. The majority of shingles installed following Hurricane Rita would likely have been rated to both ASTM D3161 [30] and ASTM D7158 [30,31]. Based on these changes in the standard test methods, it is understandable that performance in Hurricane Laura was generally better than in Hurricane Rita, despite higher wind speeds in the latter storm. However, there were still many shingle failures seen in Hurricane Laura in areas where the wind speeds were less than 67 m/s (150 mph), even though the vast majority of shingles would have been rated to this wind speed according to ASTM D7158 [14] at either 67 m/s (150 mph) or 85 m/s (190 mph) at the time of Hurricane Laura.

4 Limitations

This study was purely observational – the results and conclusions of the study are based on the statistics generated by the observations rather than controlled experimental testing. Therefore, this study identifies associations between roof age, roof shape, wind speed, and roof cover damage, but it does not establish full causation. It is worth noting that the analysis was based on subjective roof damage level assessments by visual interpretation of aerial imagery using broad percentage categories. This approach was necessary because detailed inspections, material samples, and detailed building documentation were not available for the full dataset. Recent work by Walczak et al. [32] shows a more objective method to diagnose the damage in buildings using terrestrial laser scanning (TLS). However, the methodology presented in this paper was the only available option due to the limitations of the available data. Important variables such as roof level wind speed, terrain exposure, surrounding obstructions, aerodynamic shape, building height, plan dimensions, roof slope, roof structural configuration, construction quality, material specifications, installation quality, maintenance history, and previous repairs could not be fully controlled, and in many cases are not publicly available. These factors may also contribute to the observed damage patterns. The current study also required assuming the age of a roof cover if it was subjectively determined to be damaged in Hurricane Rita and through the year built if constructed after Hurricane Rita. There was a limited assessment of uncertainty in the estimates given in the manuscript. Errors could stem from the estimation of roof damage level, multiple roof replacements after Rita yielding an inaccurate assumption of roof age, renovations, and the correction of wind speeds from a standard height and terrain including any sheltering or interference effects of the nearby built and natural environment. Assumptions were made regarding the correctness of year-built information contained in Zillow and the wind ratings of the shingles described as in Section 3.2.2, which could also lead to errors if the assumptions were incorrect.

The dataset is limited to two geographic areas in Louisiana and to asphalt shingle roof covers exposed to Hurricane Laura. Therefore, the results may not be generalizable to other high wind events, construction practices, roofing systems, or design standards. The performance transition observed between 8-9 and 10-11 year-old roofs in this dataset should be treated as an empirical threshold of the analyzed sample, not as a general service life threshold. Laboratory aging tests, field sampling of sealant condition, and additional field datasets would help to validate the mechanisms suggested by the observed trends.

5 Discussion and Conclusions

In this study, there was an observed relationship between the age of a roof cover and the level of roof cover damage. There were increases in the proportion of homes with roof cover damage with increasing age for all damage levels considered. Specifically, the 25-50%, 50-75%, and 75-100% roof cover damage levels increased at roof cover ages of 8-9, 10-11, and 12-13 years, respectively. When considering roof shape in addition to roof age, hip roofs appeared to be more susceptible to roof cover damage with an increase in roof age than gable roofs, especially for roof ages 8 years and older, but this would need to be explored further given findings from previous studies. For homes damaged in both Hurricane Rita and Hurricane Laura, notably higher roof cover damage levels were observed for much lower wind speeds in Hurricane Rita, which was unsurprising given changes in shingle test requirements over that time period.

The results presented in this manuscript are consistent with findings from prior research that show that asphalt shingle performance is linked to sealant condition and increased unsealing that happens over time [2,9,10]. However, this manuscript was able to build upon previous work by making improved assumptions regarding roof cover age.

Previous studies had to rely only on building age as a proxy for roof age, which is an assumption that works for newer buildings, but becomes increasingly challenging for older buildings given the increased likelihood that a roof replacement may have occurred. The presented observations in this manuscript provide further evidence that the proportion of homes with visible roof cover damage increases with age. This agreement strengthens the hypothesis that roof cover age contributes to the level and frequency of damage observed after hurricane events. However, this study does not include material testing of shingles or direct sealant measurements and relies on observations rather than experimental verification.

Additionally, previous studies show that hip roofs perform better than gable roofs under extreme wind loading [26, 27, 28]. The present study shows an agreement with these findings for younger roofs, where newer hip roofs were generally less frequently damaged than newer gable roofs. However, the study shows that older hip roofs perform worse than gable roofs.

The comparison between Hurricanes Rita and Laura also provides useful insights for the role of changing asphalt shingle standards. Despite the higher estimated wind speeds in Laura, the subset of roofs damaged in both storms had higher damage proportions during Rita at lower wind-speed ranges. This pattern is consistent with the evolution of ASTM shingle wind resistance standards and suggests that roofs may have benefited from improved shingle ratings. At the same time, the presence of substantial damage during Laura at wind speeds below ASTM D7158 ratings indicates that laboratory ratings for new, sealed shingles do not fully represent aged, installed roofs exposed to weathering, installation variability, and repairs.

The contribution of this manuscript is not a fragility model or a controlled material aging experiment. Instead, it provides a large, field observational dataset showing that roof cover age is an important variable to consider when interpreting asphalt-shingle damage after high-wind events. The findings may not be generalizable outside the studied regions, wind-speed ranges, and roof cover type without additional validation.

Future work will aim to improve upon the limitations of this initial study. The development of models and tools to assess damage objectively and in an automated manner will help alleviate some of the subjectivity in the current research. Further investigation is ongoing with additional datasets of a similar type, including damage data from Hurricanes Gustav in 2008 and Ida in 2021, which both made landfall further east in Louisiana [9]. Other future work could also develop fragility curves or investigate the propagation of failure within roof systems similar to the work presented by Ksit and Szymczak-Gracyzk [33].

Credit authorship contribution statement

Wesam Mohamed: Writing – review & editing, Visualization, Investigation, Data curation, Formal analysis, Validation, Methodology.

Rachel Kovar: Writing – original draft, Investigation, Visualization, Data curation, Formal analysis.

Franklin Lombardo: Writing – review & editing, Writing – original draft, Resources, Formal analysis, Methodology, Conceptualization, Funding acquisition, Project administration, Supervision.

Tanya Brown-Giammanco: Writing – review & editing, Writing – original draft, Methodology, Conceptualization, Formal analysis.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The work described in this paper was supported by the Insurance Institute for Business & Home Safety

Data Availability

Data will be made available on request.

Disclaimer

No formal investigation has been conducted to evaluate all potential sources of uncertainty or error associated with the wind damage estimates.

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

These opinions, recommendations, findings, and conclusions do not necessarily reflect the views or policies of NIST or the United States Government.

References

[1] The Asphalt Roofing Manufacturers Association (ARMA), 2011. The Bitumen Roofing Industry: A Global Perspective. ARMA, Washington, DC, 81 pp. Available online at: https://www.asphaltroofing.org/wp-content/uploads/2017/05/The_Bitumen_Roofing_Industry_-_A_Global_Perspective.pdf

[2] Dixon, C.R., Masters, F.J., Prevatt, D.O., Gurley, K.R., Brown, T.M., Peterka, J.A., Kubena, M.E., 2014. The influence of unsealing on the wind resistance of asphalt shingles. J. Wind Eng. Industr. Aerodyn., 130, 30-40. https://doi.org/10.1016/j.jweia.2014.03.016.

[3] Dixon, C.R., Masters, F.J., Prevatt, D.O., Gurley, K.R., 2012. An historical perspective on the wind resistance of asphalt shingles. RCI Interface, 30 (5), pp. 4-14. Available online at: https://iibec.org/wp-content/uploads/2012-05-dixon-masters-prevatt-gurley.pdf.

[4] RICOWI, Inc., 2006. Hurricanes Charley and Ivan Wind Investigation Report. Roofing Industry Committee on Weather Issues, Inc., McDonough, GA, 260 pp. Available online at: https://www.ricowi.com/reports/REPORT-2006-HRCN-CHARLEY-DL.

[5] RICOWI, Inc., 2007. Hurricane Katrina Wind Investigation Report. Roofing Industry Committee on Weather Issues, Inc., Powder Springs, GA, 202 pp. Available online at: https://www.ricowi.com/reports/REPORT-2007-HRCN-KATRINA-DL.

[6] RICOWI, Inc., 2010. Hurricane Ike Wind Investigation Report. Roofing Industry Committee on Weather Issues, Inc., Powder Springs, GA, 364 pp. Available online at: https://www.ricowi.com/reports/REPORT-2010-HRCN-IKE-DL.

[7] RICOWI, Inc., 2018. RICOWI Wind Investigation: Hurricane Irma, Florida. Roofing Industry Committee on Weather Issues, Inc., Clinton, OH, 87 pp. Available online at: https://www.ricowi.com/reports/REPORT-2018-HRCN-IRMA-DL.

[8] RICOWI, Inc., 2019. RICOWI Wind Investigation: Hurricane Michael, Florida. Roofing Industry Committee on Weather Issues, Inc., Princeville, HI, 159 pp. Available online at: https://www.ricowi.com/reports/REPORT-2019-HRCN-MICHAEL-DL.

[9] Liu, Z., Pogorzelski, H., Masters, F.J., Tezak, S., Reinhold, T.A., 2010. Surviving nature's fury: performance of asphalt shingle roofs in the real world. RCI Interface, 11, pp. 29-44. Available online at: https://ibhs.org/wp-content/uploads/member_docs/Surviving-Natures-Fury-Performance-of-Asphalt-Shingle-Roofs-in-the-Real-World_IBHS.pdf.

[10] Gurley, K.R., Masters, F.J., 2011. Post 2004 hurricane field survey of residential building performance. ASCE Nat. Hazard. Rev., 12 (4), pp. 177-183. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000044.

[11] Brown, T. M., Liang, D., and Womble, J. A., 2012. Predicting ground-based damage states from windstorms using remote-sensing imagery. Wind Struct. 15, 369–383. https://doi.org/10.12989/was.2012.15.5.369.

[12] ASTM, 2024. Standard test method for wind resistance of asphalt shingles (uplift force/uplift resistance method) ASTM D7158/D7158M-24a. ASTM Volume 04.04, 17 pp. DOI: 10.1520/D7158_D7158M-24A.

[13] Marshall, T.P., Herzog, R.F., Morrison, S.J., 2004. Hail damage to asphalt roof shingles. In: Proc. of the 22nd Conference on Severe Local Storms, American Meteorological Society, Hyannis, MA.

[14] ASTM, 2016. Standard test method for wind resistance of asphalt shingles (uplift force/uplift resistance method) ASTM D7158/D7158M-16. ASTM Volume 04.04, 16 pp. DOI: 10.1520/D7158_D7158M-16.

[15] ASTM, 2025. Standard test method for wind resistance of steep slope roofing products (fan-induced method) ASTM D3161/D3161M-20. ASTM Volume 04.04, 4 pp. DOI: 10.1520/D3161_D3161M-20R25.

[16] ASTM, 2024. Standard test method for measurement of asphalt shingle mechanical uplift resistance ASTM D6381/D6381M-24. ASTM Volume 04.04, 11 pp. DOI: 10.1520/D6381_D6381M-24.

[17] National Weather Service. (2016, September 10). *June 4, 2007 severe weather - Northern Vermilion Parish flooding & historic Lake Charles hailstorm*. U.S. Department of Commerce. https://www.weather.gov/lch/e060407

[18] Storm Prediction Center (SPC), 2024, "The US Tornado Database (1950-2023)," *National Oceanic and Atmospheric Administration (NOAA)*.

[19] International Code Council (ICC), 2006. International Residential Code (IRC). https://codes.iccsafe.org/content/IRC2006P7 (Accessed November 18, 2025).

[20] International Code Council (ICC), 2009. International Residential Code (IRC). https://codes.iccsafe.org/content/IRC2009P11 (Accessed November 18, 2025).

[21] NOAA, 2024. Hurricane Rita Imagery. https://geodesy.noaa.gov/storm_archive/storms/rita/RITA0000.HTM (Accessed January 27, 2025).

[22] NOAA, 2024. Hurricane Laura Imagery. https://storms.ngs.noaa.gov/storms/laura/index.html#7/29.862/-93.567 (Accessed January 27, 2025)

[23] Kovar, R.N., Brown-Giammanco, T.M., Lombardo, F.T., 2018. Leveraging remote-sensing data to assess garage door damage and associated roof damage. Front. Built Environ., 30 October 2018, https://doi.org/10.3389/fbuil.2018.00061.

[24] Powell, M. D., Houston, S. H., Amat, L. R., Morisseu-Leroy, N., 1998. The HRD real-time hurricane wind analysis system. J. Wind Eng. Ind. Aerodyn. 77–78, 53–64. doi: 10.1016/S0167-6105(98)00131-7.

[25] Merhi, A., Brown-Giammanco, T.M., Roueche, D.B., Wood, R.L., Murphy, T.A., Standohar-Alfano, C.D., Childress, O., Stetzer, T., Godfrey, E.S., Godfrey, C.M., Souhrada, A.J., 2025. Damage assessment of the 2020 Monroe, Louisiana, tornado using different remote-sensing methods and Enhanced Fujita Scales. Nat. Hazards Rev. 04025062-01- 04025062-22, 27-1. doi: 10.1061/NHREFO.NHENG-2367.

[26] Taher, R., 2007. Design of low-rise buildings for extreme wind events. J. Archit. Eng., 13(1), pp. 54–62., https://doi.org/10.1061/(asce)1076-0431(2007)13:1(54).

[27] Stevenson, S.A., Kopp, G.A., El Ansary, A.M., 2018. Framing failures in wood-frame hip roofs under extreme wind loads. Front. Built Environ., 06 February, 2018. https://doi.org/10.3389/fbuil.2018.00006.

[28] Brown-Giammanco, T.M., Giammanco, I.M., Pogorzelski, H., 2018. Hurricane Harvey Wind Damage Investigation. Insurance Institute for Business & Home Safety, Tampa, FL, 36 pp. Available online at: https://ibhs.org/wp-content/uploads/member_docs/Hurricane-Harvey-Wind-Damage-Investigation_IBHS.pdf.

[29] ASTM, 1999. Standard test method for wind resistance of steep slope roofing products (fan-induced method) ASTM D3161-99a. ASTM Volume 04.04, 3 pp.

[30] ASTM, 2003. Standard test method for wind resistance of steep slope roofing products (fan-induced method) ASTM D3161-03b. ASTM Volume 04.04, 3 pp.

[31] ASTM, 2005. Standard test method for wind resistance of sealed asphalt shingles (uplift force/uplift resistance method) ASTM D7158/D7158M-05. ASTM Volume 04.04, 05 pp. DOI: 10.1520/D7158-05

[32] Walczak, Z., Ksit, B., Szymczak-Graczyk, A., 2024. Decision-support tools for diagnosing and selecting the optimal method of repairing buildings. Bulletin of the Polish Academy of Sciences: Technical Sciences, 72 (6), Article e151382. https://doi.org/10.24425/bpasts.2024.151382.

[33] Ksit, B., Szymczak-Graczyk, A., 2019. Rare weather phenomena and the work of large-format roof coverings. University of Zielona Gora, Civil and Environmental Engineering Reports, 29 (3), pp. 123–133. https://doi.org/10.2478/ceer-2019-0029.

Highlights

- An observational analysis of 623 asphalt shingle roofs damaged during Hurricane Laura (2020) shows an association between roof age and damage severity.
- Roofs older than eight years exhibited a notable increase in observed damage levels compared to roofs less than eight years, with 97% of 14–15-year-old roofs within the analyzed sample experiencing some level of failure.
- Hip roofs were more susceptible to roof cover damage with an increase in roof age than gable roofs, especially for roof ages 8 years and older.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.