A Preliminary Report

Damage Assessment of Woodframe Residential Structures in the Wake of Hurricane Katrina

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Project Webpage: http://www.engr.colostate.edu/~jwv/hurricane-Katrina-woodframe/ (Beginning Nov. 1)
Disclaimer

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Abstract

One of the worst natural disasters in U.S. history is hurricane Katrina, which made landfall on August 29, 2005 at 7:10 a.m. in Plaquemines Parish, LA. Tragically, Katrina caused widespread damage and loss of life in several states but also provided an opportunity to collect data on woodframe construction which may be useful for design engineers and building code officials in order to design safe and strong buildings in the future. The objective of this study was to gather and process perishable wind damage data on residential woodframe structures in non-flooded regions of Mississippi that can be used by the research and design code development community to improve the performance of woodframe structures to strong wind loading.

Introduction

This preliminary report is intended to provide an overview of the upcoming final project report to the National Science Foundation (NSF) as well as the project web site, which is currently under development and will be operational by November 1, 2005. This report is not intended to be conclusive, but rather to identify the NSF-sponsored woodframe damage assessment team’s immediate observations following the trip to the Gulf Coast region. The full final project report will also be made available to the general public via the project web site described below.

Project Scope

This study consisted of three days of data acquisition of wind damage to woodframe structures along the U.S. Gulf Coast. A total of 27 case studies shown in Table 1, ranging from entire subdivisions to individual woodframe structures were examined in detail. Significant wind damage was observed for many additional woodframe structures, but each is not discussed here because failure mechanisms were not believed to be different than those presented herein. The structures/subdivisions presented in Table 1 will be addressed individually, i.e. structure ID’s tied back to photographs and discussion, in the final project report and the project webpage. Figure 1 presents a geographical information system (GIS) map with hurricane Katrina’s NOAA-estimated wind speeds,
major roadways, and the location of each structure examined. A more detailed map was created and will be located on the project webpage at: http://www.engr.colostate.edu/~jwv/hurricane-Katrina-woodframe in late 2005.

TABLE 1: Case studies to be presented in the final report and web page

<table>
<thead>
<tr>
<th>Structure ID</th>
<th>Structure Name / Note</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Date Examined</th>
<th>Time Examined</th>
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<tbody>
<tr>
<td>1</td>
<td>HWY 49 porch collapse</td>
<td>30.822</td>
<td>-89.137</td>
<td>9/23/2005</td>
<td>12:58:00 PM</td>
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<tr>
<td>2</td>
<td>CMU building lost 2nd roof</td>
<td>30.782</td>
<td>-89.138</td>
<td>9/23/2005</td>
<td>1:40:00 PM</td>
</tr>
<tr>
<td>3</td>
<td>porch collapse</td>
<td>30.708</td>
<td>-89.134</td>
<td>9/23/2005</td>
<td>1:51:00 PM</td>
</tr>
<tr>
<td>4</td>
<td>convenience store collapse</td>
<td>30.498</td>
<td>-89.106</td>
<td>9/23/2005</td>
<td>2:30:00 PM</td>
</tr>
<tr>
<td>5</td>
<td>flooded apartment complex</td>
<td>30.399</td>
<td>-89.043</td>
<td>9/23/2005</td>
<td>3:42:00 PM</td>
</tr>
<tr>
<td>6</td>
<td>yellow garage - door blown in</td>
<td>30.445</td>
<td>-89.090</td>
<td>9/23/2005</td>
<td>5:38:00 PM</td>
</tr>
<tr>
<td>7</td>
<td>two car garage - center support blew in</td>
<td>30.444</td>
<td>-89.088</td>
<td>9/23/2005</td>
<td>6:07:00 PM</td>
</tr>
<tr>
<td>8</td>
<td>panel loss newer neighborhood</td>
<td>30.446</td>
<td>-89.084</td>
<td>9/23/2005</td>
<td>6:40:00 PM</td>
</tr>
<tr>
<td>9</td>
<td>corner roof uplift</td>
<td>30.446</td>
<td>-89.084</td>
<td>9/24/2005</td>
<td>8:47:00 AM</td>
</tr>
<tr>
<td>10</td>
<td>front porch post shift</td>
<td>30.446</td>
<td>-89.084</td>
<td>9/24/2005</td>
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</tr>
<tr>
<td>11</td>
<td>gable vent blown in</td>
<td>30.456</td>
<td>-89.082</td>
<td>9/24/2005</td>
<td>9:10:00 AM</td>
</tr>
<tr>
<td>12</td>
<td>newer subdivision - garage door blown in</td>
<td>30.457</td>
<td>-89.073</td>
<td>9/24/2005</td>
<td>9:33:00 AM</td>
</tr>
<tr>
<td>13</td>
<td>Windsong neighborhood</td>
<td>30.465</td>
<td>-89.068</td>
<td>9/24/2005</td>
<td>10:03:00 AM</td>
</tr>
<tr>
<td>14</td>
<td>Newer subdivision - south of Windsong</td>
<td>30.461</td>
<td>-89.073</td>
<td>9/24/2005</td>
<td>10:22:00 AM</td>
</tr>
<tr>
<td>15</td>
<td>Diamond Head - condo roof loss</td>
<td>30.385</td>
<td>-89.363</td>
<td>9/24/2005</td>
<td>11:48:00 AM</td>
</tr>
<tr>
<td>16</td>
<td>newer subdivision - storm surge in places</td>
<td>30.451</td>
<td>-89.024</td>
<td>9/24/2005</td>
<td>1:53:00 PM</td>
</tr>
<tr>
<td>17</td>
<td>Brighton Place - new subdivision</td>
<td>30.416</td>
<td>-89.031</td>
<td>9/24/2005</td>
<td>2:30:00 PM</td>
</tr>
<tr>
<td>18</td>
<td>Plantation - 3 story apt complex</td>
<td>30.405</td>
<td>-89.004</td>
<td>9/24/2005</td>
<td>3:00:00 PM</td>
</tr>
<tr>
<td>19</td>
<td>Thomasville Apartments - brick veneer loss</td>
<td>30.401</td>
<td>-89.002</td>
<td>9/24/2005</td>
<td>3:04:00 PM</td>
</tr>
<tr>
<td>20</td>
<td>CMU commercial structure - complete wall failure</td>
<td>30.401</td>
<td>-88.979</td>
<td>9/24/2005</td>
<td>3:48:00 PM</td>
</tr>
<tr>
<td>21</td>
<td>new construction south of Back Bay of Biloxi</td>
<td>30.413</td>
<td>-88.970</td>
<td>9/24/2005</td>
<td>4:29:00 PM</td>
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<tr>
<td>22</td>
<td>Tire Kingdom</td>
<td>30.436</td>
<td>-88.893</td>
<td>9/25/2005</td>
<td>8:10:00 PM</td>
</tr>
<tr>
<td>23</td>
<td>Cypress Points</td>
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<td>-89.137</td>
<td>9/25/2005</td>
<td>9:12:00 AM</td>
</tr>
<tr>
<td>25</td>
<td>Lake Village Estates</td>
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<td>-89.164</td>
<td>9/25/2005</td>
<td>10:30:00 AM</td>
</tr>
<tr>
<td>26</td>
<td>two story ranch</td>
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<td>-89.316</td>
<td>9/25/2005</td>
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<tr>
<td>27</td>
<td>small detached garage</td>
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<td>9/25/2005</td>
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</tr>
</tbody>
</table>

The trip began in Tuscaloosa, AL and the team traveled down Interstate 59/20 toward Hattiesburg, MS. Initial inspections were performed in Hattiesburg and it was determined that the majority of woodframe residential damage there was related to the uprooting of trees in the heavily wooded neighborhoods.

A significant number of woodframe structures were examined in and around the city of Gulfport, MS. Structures were also examined in and around Biloxi, MS as well as several rural areas of Mississippi, as shown in Figure 1. Note that the majority of structures
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Investigated in this study are within five miles of Interstate 10 along the Mississippi Gulf Coast.

Surge damage to woodframe structures, although quite prevalent along much of the coastal areas, is not addressed in this preliminary report. Design codes for woodframe structures do not currently address that type of loading.

This preliminary report is divided into (1) structural observations, (2) non-structural observations, and (3) general observations:

FIG 1. Estimated ground level wind speeds produced by hurricane Katrina along with locations of structures investigated in this study
Structural Observations

Observation No. 1 – Lack of uplift load path
In the design of structures for wind loading (see ASCE – 7, 2005, for a detailed explanation) it is necessary to provide a continuous load path from the roof down into the (concrete) foundation. In a noticeable number of structures examined this continuous load path was not present. Figure 2 shows an example of a single-family dwelling with brick veneer whose wood support columns under the porch overhang were not anchored into the concrete. Presumably, the overhang had been designed for gravity loads and was able to resist moderate winds due to its self (dead) weight. However, with the wind gusts associated with hurricane Katrina the porch uplifted, the column was blown out, and then the overhang collapsed due to lack of support. Figure 2 also shows the results of not anchoring the sill plate to the foundation. The wall pier between the two single car garage doors was not anchored, and as a result the bottom pushed inward in excess of 12 inches, nearly causing collapse of that portion of the structure.

In many cases the porch roof diaphragm is framed back into the roof system, thus failure of the porch overhang resulted in a significant breech of the structural envelope and subsequent water damage from numerous inches of wind-driven rain resulted. It also allowed the attic areas to become internally pressurized, further adding to structural damage.

The same type of failure was seen in carports, whose support columns/posts were not properly anchored to the concrete. Figure 3 shows an example of this type of failure for a carport. This type of failure was not seen when wood to concrete hold downs were used.
at the base of support posts. The correct use of this type of connector is shown pictured in Figure 4. The aesthetic vinyl wrap was peeled off but the support post, and subsequently the porch overhang and roof, remained intact.

A lack of wind load path was observed in many cases during the site visits. Figure 5 shows a photograph of a CMU wall located next to a light commercial woodframe building. The CMU wall was essentially free-standing as it appeared to only be connected by light gage flashing. Figure 6 shows a photograph of a similar situation where the brick veneer in a woodframe apartment building was lost once the interior of the structure became pressurized.

**Observation No. 2 – Loss of roof sheathing at corners.**

The perimeters, including corners, of roofs typically experience the highest uplift pressure during wind storms. Loss of roof sheathing was observed at the perimeters and corners in numerous cases. It was also observed that when roof sheathing was lost it was not attached with the code minimum nail spacing of 6” on-center for the perimeter and 6” on-center in the field. Figures 7 and 8 show typical roof sheathing loss as a result of hurricane Katrina winds. Using nail spacing that meets or exceeds the code minimum would have significantly reduced loss of sheathing in the Mississippi Gulf Coast region.
Observation No. 3 – Gable end wall loss
A common failure that was observed was the loss of sheathing on the gable end walls as shown in Figures 9 and 10. One likely cause, in addition to the loss of vinyl siding described in observation No. 7, is that air entered through attic vents or other means and pressurized the attic dislodging one or more sections of sheathing. This resulted in the breech of the building envelope and penetration by many inches of wind driven rainwater. The rainwater saturated the ceiling insulation resulting in failure of the gypsum/drywall ceiling. Figure 11 shows a photograph from inside the second floor bedroom of the house in Figure 9. Once the structure was fully breached, significant water damage occurred. The structure(s) shown in these photographs had been saturated with rain water and was in the process of complete renovation. According to the homeowner, the repair estimate was equal to the cost of the home when it was purchased new in 1999.
Observation No. 4 – Use of conventional\(^1\) construction in high wind region

We believe that most or all of the construction in this region is based on conventional construction which does not require any engineering calculations. An example of this is shown in Figure 12 where four foot wide braced panels were placed at the ends of a 25-ft exterior wall without any hold downs to resist lateral (e.g., wind) forces, as typically required by the conventional building code provisions. However, ASCE - 7 (2005) shows this region having a design wind speed of 130 to 140 mph. These high winds would result in these areas falling out of the scope of conventional building code provisions, thus the need for engineering calculations.

\(^1\) The term “conventional construction” is used here as a system constructed entirely of repetitive horizontal and vertical wood light-framing members complying with NDS, the IRC, or section 2308 of the IBC.
for engineered construction. This results in engineering calculation for the width of shear wall (in place of braced panel) along with nailing and anchoring requirements. As an alternative to detailed calculations, these structures could have followed the Woodframe Construction Manual - High Wind Edition (AF&PA 1995) which is a prescriptive code but is based on engineered loads and load paths or they could have used the engineered wood code (NDS 2005) which requires engineering calculations. If the wall in Figure 12 was designed using engineered code, the shear walls at the ends of the wall may have been more than four feet long with stricter nailing requirement and hold downs at the ends of the shear walls. It appears that code jurisdictions and builder(s) seem to be familiar with conventional construction in this region but there were multiple cases where homes should not fall under this provision.

**Observation No. 5 – Details were Key**

It was observed that seemingly small details that were not addressed, such as a lack of nails in hurricane clips, resulted in failure. Figure 13 shows the remains of a condominium roof that lifted off after four hours of wind gusting (according to an eyewitness). Figure 14 shows a close-up of a hurricane tie that did not have the recommended number of nails. Another example of inadequate load transfer was also observed in the same condominium community. The entire truss system lifted off the roof and the top plate came off with it. In that case, the truss uplift forces were transferred adequately to the top plate, but the top plate had no mechanism to transfer the load to the wall assembly, since the top plate was not anchored properly. The result was complete loss of the roof system.

Further, in Figure 15 is a strap that has been field-modified in the shape of an “L”. It is not clear what the design requirements are for this particular connection, but such modification renders the strap ineffective for uplift resistance. Connections such as this strap should always be installed in accordance with the manufacturer’s recommendations to ensure that it performs as expected.
Non – Structural Observations

Observation No. 6 – Roof Coverings
There were innumerable cases where roof shingles were lost, and many were already covered with blue tarp. Based on investigation as well as discussions with homeowners, architectural roof shingles tended to perform better than normal roof shingles. Figure 16 shows the loss of roof covering for a typical woodframe residential structure in the area. Loss of shingles was common to both older and newer structures in all areas studied even though these areas did not experience winds in excess of 100 mph.

Observation No. 7 – Connection of Vinyl Siding
Although vinyl siding is not typically considered a structural material, it assists in maintaining the integrity of the building envelope. Manufacturer recommendations state that vinyl siding be connected to the wood framing members with a penetration of at least...
Damage to trim pieces and soffits was routinely observed. Winds in the region (see Figure 1) studied were significantly below ASCE-7 (2005) design wind speeds, thus routinely observed trim damage was felt to be excessive. Figure 18 shows damage to the trim of a gable roof just to the left of the garage on a home that faired quite well. Many two-story homes just across the street did not perform very well with significant non-structural and some structural damage, as shown earlier in Figures 9, 10, 11, and 17. In this particular subdivision, one-story houses performed much better than

Observation No. 8 – Vulnerability of Soffits and Trim Pieces

FIG 17. The result of vinyl siding and sheathing loss left just a shell for many of the homes in this subdivision

FIG 18. Damage to the top right trim piece on the roof just left of the garage. This was the only damage to this one-story house with a hip roof.
two-story houses, possibly due to localized wind effects.

**Observation No. 9 – Attic vents**
Attic vents were a common entrance for wind flow resulting in pressurization of the attic and failure of the roof sheathing. Figure 19 shows a damaged attic vent and roof sheathing in a 1970’s one-story home. Attics that were vented using perimeter ventilation near the soffit typically performed better than structures with attic vents located on the gable. This trend was common for both older and newer woodframe residential construction.

![FIG 19. Attic vent allowed attic to pressurize and roof sheathing to fail.](image1)

**General Observations**

**Observation No. 10 – Structural Age Played a Factor**
Although there were many older residential woodframe houses that performed well, the general trend was that newer homes tended to sustain less structural and non-structural damage. Figure 20 shows a picture of new homes, very recently constructed, in the foreground and older circa 1970’s homes in the background. The difference in the sustained damage levels was notably higher in the older structures. It may be inferred from this that design code changes, following Hurricane Andrew in 1992, were likely successful.

![FIG 20. Newer home with very little structural or non-structural damage in the foreground. Older neighborhood in the background with most structures having significant damage.](image2)
Observation No. 10 – Roof Types
Hip roofs performed significantly better than gable roofs. Figure 20 on the previous page is an example of a typical gable roof, while Figure 21 is an example of a hip roof that performed very well during the hurricane. This was the trend throughout the study area, shown in Figure 1, and for both one- and two-story houses.

Preliminary Conclusions and Recommendations

The following conclusions are intended to be preliminary and will be supplemented in the final report. The project web page will have a hyperlinked case study site map, satellite photos of sites, damage description and reasons for failure, and 6 to 10 photos per case study.

1.) Woodframe residential and light commercial structures that followed design codes and guidelines performed well during hurricane Katrina wind loading. Thus, there is circumstantial evidence to suggest that design code revisions following hurricane Andrew in 1992 may have been successful.

2.) Builders and inspectors seem to be familiar with conventional construction provisions. However, these provisions were used erroneously in a high wind region.

3.) A closer/heavier nailing schedule for roof sheathing would be helpful in reducing the amount of roof sheathing loss due to uplift, particularly at the edges and
corners, and result in significantly less water intrusion. In many places the code minimum spacing was not being met.

4.) Support columns/posts must be anchored to both the roof and concrete foundation, particularly in high wind regions such as the Gulf Coast.

5.) Architectural shingles tended to remain intact more often that regular roof shingles.

6.) Careful attention must be paid to all details, particularly the (correct) use of all straps and ties, to ensure a continuous load path from the roof to the foundation.

7.) Seemingly insignificant details such as the connection of non-structural siding resulting in the loss of foam board substrate can result in substantial financial loss due to water intrusion, once a breech of the building envelope occurs. Although these are non-structural issues they present important cost concerns for woodframe structures during hurricanes.

References

