

**Tornado Damage in Tuscaloosa, Alabama,
December 16, 2000**

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Abstract

In the early afternoon of Saturday, December 16, 2000, the County of Tuscaloosa, Alabama, was struck by a violent tornado that caused numerous deaths, injuries and damage. The storm was rated by the National Weather Service as an F4 on the Fujita Storm Intensity Scale. Investigation of the storm scenes revealed that the wind speeds which caused the observed damage were close to those usually associated with the F2 damage scale because of: (1) the basic design wind speed of the area, (2) the type of construction, (3) the quality of construction, and (4) the relatively high translational speed of the storm. Accounting for this criteria, the strongest damage caused by the Tuscaloosa Tornado can be explained by wind speeds corresponding to an F2 storm. Furthermore, the loss of life in this wind event is related to the type and quality of construction found in the damaged area.

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Introduction

In the early afternoon of Saturday, December 16, 2000, the County of Tuscaloosa, Alabama, was struck by a violent tornado that caused 12 deaths and 75 injuries, and damaged or destroyed 265 structures at an estimated cost of \$12.5 million. The tornado was spawned by a supercell thunderstorm that originated in Mississippi and was first sighted in Southwestern Tuscaloosa County on the west side of the Warrior River. The first structural damage was in Englewood Meadows, where a manufactured home was overturned and several site-built homes were damaged. The tornado continued in a northeasterly direction where it destroyed the nearly complete and not yet occupied Englewood Village Market Place shopping center; crossed SR 69 and struck the Hinton Place and Hillcrest Meadows subdivisions, causing damage to site-built homes; continued northeast and struck the Bear Creek Mobile Home Park; crossed US 82 downing trees and power lines and struck the Woodland Forrest subdivision; then crossed I-20/59 and struck the JVC Manufacturing Plant and several other commercial structures. The National Weather Service (NWS) issued the first warning at 10:00 am; the tornado first touched ground at 12:54 pm and dissipated at 1:12 pm. Given a storm path of 750 yards wide and 18 miles long, the translational storm speed was calculated as approximately 60 mph (29 m/s).

The storm was rated by the NWS as an F4 on the Fujita Storm Intensity Scale (see **Appendix A**). By definition, an F4 tornado represents “*Devastating Damage*, whole frame houses leveled, leaving piles of debris; steel structures badly damaged; trees debarked by small flying debris; cars and trains thrown some distances or rolled considerable distances; large missiles generated” (Fujita, 1971). The design wind speed for Tuscaloosa County is a fastest-mile wind speed of 70 mph (33 m/s) per the Standard Building Code (SBCCI) 1999 edition. This equates to a 3-second gust wind speed relationship of 84 mph (40 m/s). The SBCCI references the *ASCE Standard for Minimum Design Loads for Buildings and Other Structures* (ASCE 7) for the calculation of wind loads (refer to **Appendix A** for relation of wind speeds – fastest ¼-mile to 3-second gust to fastest-mile). Even though residential structures were not designed specifically for this wind speed (because residential structures are not professionally engineered structures), their reserve strength should exceed design loads by a factor of 2 to 3. Since wind loads vary with the square of the wind speed, the reserve strength would relate to a design wind speed by a factor of 1.4 to 1.7. This factor would suggest that 3-second gust wind speeds in the range of 118 mph to 143 mph (56 m/s to 68 m/s) could overcome the reserve strength and totally destroy a structure. In addition to wind speeds, if a structure is located near the center of the tornado path, the long duration of winds can completely remove the home from its slab foundation (Simiu, 1998). As a result, the Tuscaloosa storm rating of F4 was high due to the failure of the Fujita Scale to accurately account for: (1) the basic design wind speed of the area, (2) the type of construction, (3) the quality of construction, and (4) the relatively high translational speed of the storm.

Main Damage Observations

Figure 1 depicts the storm's path. The initial tornado touched down in Englewood Meadows, where a mobile home was overturned and several homes were damaged.

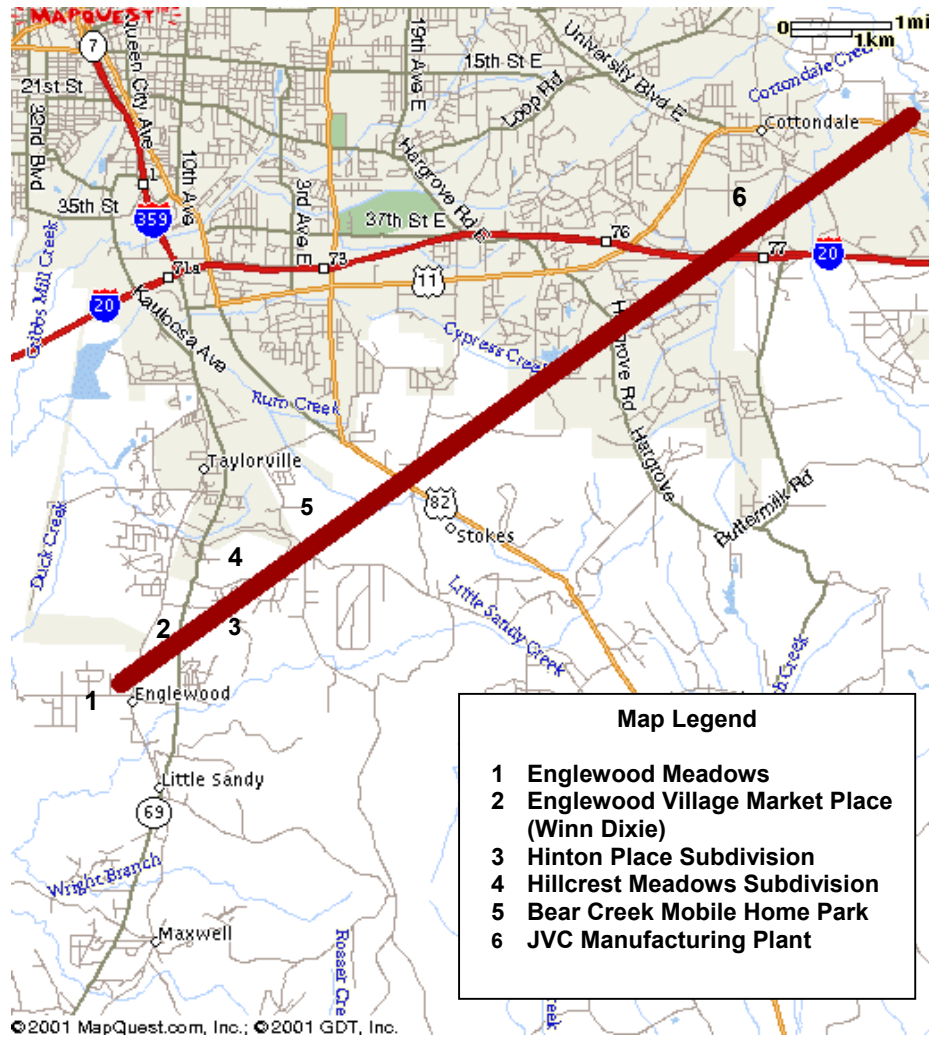


Figure 1. Storm Path

The mobile home in Figure 2 represents the classic definition of the F1 description – “trailer houses pushed or overturned” (Fujita, 1971). The trailer had tie-downs and was underpinned. Photographs of the adjacent homes, Figure 3, present damage consistent with the F1 description, “roof surfaces peeled off and windows broken” (Fujita, 1971). However, the assigned wind speeds for an F1 tornado by Fujita would approach the reserve strength of the site built homes and presumably can devastate the mobile home. The assumption drawn was that either the homes were constructed better than the standard or that the wind speed better fit the category of F0 winds.



Figure 2. Englewood Meadows Mobile Home



Figure 3. Englewood Meadows Home

From Englewood Meadows the tornado proceeded in a northeasterly direction crossing open ground until it struck the nearly complete and not yet occupied Englewood Village Market Place which contained the Winn Dixie Supermarket. The shopping village was constructed of built-up roofing on metal decking attached to steel bar joists bearing on joist-girders, columns and unreinforced masonry (URM) walls. The joist and girder spans were long, and the URM walls were tall (see Figures 4 and 5).



Figure 4. Englewood Village Market Place, leeward wall



Figure 5. Englewood Village Market Place, windward wall

The shopping center building was under construction and was nearly complete; however, the window wall systems had not been installed. Therefore, for wind analysis purposes, the building would be considered as a partially enclosed structure. The wind forces acting upon the structure would have included both external and internal pressures. The combination of these forces tore the decking from the joists, thereby snarling the light steel structural elements and pulling down the URM walls. Further evidence of the internal pressurization is shown in Figure 6. The rolling doors, which would have experienced windward external forces, remained in place due to the negating internal pressures, while the roof deck experienced the combination of internal and external



Figure 6. Englewood Village Market Place, internal pressurization

pressures and was subsequently removed. Per ASCE-7, the internal pressure coefficient for a partially enclosed building would have increased the total roof uplift pressures by about 67%, thereby producing failure at a lower than expected wind load. Therefore, failure of the URM building, as predicted by the scale for an F3 storm, would have occurred at a much a lower wind speed, similar to an F1 or F2 storm.

From Englewood Village Market Place, the storm crossed SR 69 and struck the residential subdivisions of Hinton Place and Hillcrest Meadows, respectively. As reported by the NWS, the storm was narrow, about 750 yards wide (686 m) and the translational speed across the ground was near 60 mph (29 m/s). The homes in these subdivisions are believed to be less than 20 years old and would have been constructed under code authority. The Hinton Place home in Figure 7 was near the center of the vortex and sustained substantial structural damage to the roof and second floor wall.

Hillcrest Meadows was adjacent to and downwind from Hinton Place. Figure 8 portrays a line of homes on the windward side of the subdivision. The home in the foreground was totally destroyed and was presumably under the vortex of the tornado. This photo also indicates the progression of damage (from most to least). Roof damage was predominate in both subdivisions, with wall and other major damage only occurring under or near the narrow vortex.



Figure 7. Hinton Place Residence, near vortex



Figure 8. Hillcrest Meadows Residence, showing gradation of damage from center of tornado

As previously mentioned, considering construction standards and the reserve strength factors, the residence in Figure 8 could have been destroyed by winds in a range for an F2 tornado. The level of damage to the adjacent homes further supports this theory and demonstrates the range of wind speeds away from the vortex.

The generation of missiles from the storm debris is often an indicator of wind strength. According to Fujita's report, "light object missiles" begin to be generated by an F2 storm (Fujita, 1971). Investigation of the storm sites revealed only minimal missile generation. The most significant missiles was light-gage metal roof decking blown from Englewood Village that was deposited in both Hinton Place and Hillcrest Meadows subdivisions (Figure 9). Few missiles were found "prickling" structures; the few found were either fence pickets or small pieces of studs or rafters (Figure 10). Furthermore, although debris was generated by the storm at these sites, the debris was not carried downwind, as is common for a higher strength storm, i.e., F2 or greater (Figure 11).



Figure 9. Sheet Metal Missile, Hinton Place



Figure 10. Missiles, Hillcrest Meadows

Apparently, the storm lifted between Hillcrest Meadows and Bear Creek Trailer Park, since Hillcrest High School, which was located between the two sites, received only superficial landscaping damage (Figure 11).



Photo by Brian Peters, NWS

Figure 11. Hillcrest Meadows Subdivision



Photo by Brian Peters, NWS

Figure 12. Bear Creek Aerial

Figure 12 is an aerial view of the storm path through the Bear Creek area. Close inspection of this photo reveals that large amounts of debris were generated by the destructive storm, with some debris being carried as far as the tree line. It should be noted that little, if any, of this debris was found beyond the tree line. The massive destruction of these mobile homes attests to their nearness to the vortex, their light construction, and the propensity of these lightweight materials to be transported by high wind.

The age and general condition of the mobile homes affected by the Tuscaloosa Tornado is unknown. It is known that the state of Alabama and the Standard Building Code (SBCCI), to which the City of Tuscaloosa subscribes, specifically requires mobile home tie-downs and anchoring systems. Figure 2 shows an overturned mobile home with broken ties and Figure 13 shows further evidence of tie-downs broken by the removal of a mobile home.



Figure 13. Bear Creek Mobile Home Site with broken tie-downs

Assuming the tie-downs were sufficient in number and the installation of the anchors were in accordance to building code, numerous mobile homes were still blown from their moorings, and nine deaths resulted in the Bear Creek Mobile Home Park. The strength of the mobile home construction and strength of the winds causing the destruction therefore becomes the issue. Prior to 1976, there were no wind resistance standards for the mobile home industry. Since that time, the Federal Department of Housing and Urban Development (HUD) has regulated the manufactured home industry. Included in the HUD regulations are requirements for the design of manufactured homes to resist wind effects, thereby establishing three wind speed zones for construction (Marshall, 1994). Zones II and III are located in hurricane regions and require a fastest-mile wind resistance of 100 mph (44.7 m/s) and 110 mph (49.2 m/s), respectively. Zone I includes all interior non-hurricane prone areas, which includes the County of Tuscaloosa. Zone I requires mobile homes to resist fastest-mile wind speeds of 65 mph (29.1 m/s). It is unknown how much reserve strength, related to wind speeds, is contained in manufactured housing. However, assuming the reserve strength in manufactured housing is comparable to site-built residential structures, then a 1.4 to 1.7 factor applied to the HUD standard would relate to a fastest-mile wind speed of 91 mph to 111 mph (43 m/s to 53 m/s). At these wind speeds, it would be expected that the reserve strength would be overcome and the structures totally destroyed. These factored wind speeds relate to strong F1 tornado or a weak F2 tornado.

Figure 14 shows the total destruction of several manufactured housing units. Accordingly, the Bear Creek area is classified at an intensity level equal to or less than

that of the Hinton Place and Hillcrest Meadows subdivisions; however, ten of the twelve storm-related deaths occurred in the Bear Creek Park. Given this similar intensity of wind speed, it can only be assumed that the large loss of life is attributed to the difference in construction types and quality of construction.



Figure 14. Destroyed Manufactured Housing, Bear Creek

From the Bear Creek Mobile Home Park, the tornado crossed US 82, downed trees and power lines, and struck the Woodland Forrest subdivision. Most of the damage to this subdivision was confined to snapped tall pines and roof and structural damage caused by falling trees. The storm then crossed I-20/59 and struck the JVC Manufacturing Plant and several other commercial buildings, causing minimal cladding damage. The tornado withdrew into the clouds several miles later.

Conclusion

Discrepancies continue regarding the Fujita damage scale definitions and the associated wind speeds. The definitions are generalized, non-technical, and do not differentiate between building types or quality of construction. Non-engineering professionals use these generalized definitions to assign storm intensity based upon their damage observations. Furthermore, there is no consideration given to the design wind speed for the geographical area. Based upon the arguments previously presented, the tornado that struck Tuscaloosa County began in Englewood Meadows as an F0, progressed to F2 strength at the Englewood Village Market Place and through Hinton Place and Hillcrest Meadows, began losing strength from F2 to F1 at Bear Creek Mobile Home Park, and decreased further from F1 to F0 at Woodland Forest and the JVC Plant. Therefore, the strongest damage caused by the Tuscaloosa Tornado can be explained by wind speeds corresponding to an F2 rating.

These conclusions are significant insofar as:

1. Loss of life can be attributed to the type and quality of construction.
2. Tornado misclassification corrupts the database used to develop design criteria for structures.
3. Assigning building failures to higher-than-actual wind speeds discourages the application and enforcement of standards, such as building codes and ASCE-7, that are capable of reducing life and property caused by most tornadoes.
4. Those individuals who assign storm intensity based upon observed damage should have technical expertise in the engineering and construction disciplines.

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APPENDIX A

Wind Speed Relationship

F-Scale	*F-Scale Wind Speed mph (m/s)	Equivalent 3-sec. Gust Wind Speed mph (m/s)	Equivalent Fastest-mile Wind Speed mph (m/s)
F0	40-72 (17.9-32.2)	45-77 (20.1-34.4)	35-63 15.7-28.2
F1	73-112 (32.3-50.1)	78-118 (34.5-52.8)	64-99 (28.3-46.1)
F2	113-157 (50.2-70.2)	119-163 (52.9-72.4)	100-137 (46.2-64.8)
F3	158-206 (70.3-92.1)	164-210 (72.5-93.9)	138-184 (64.9-84.5)
F4	207-260 (92.2-116.3)	211-262 (94-117.6)	185-236 (84.6-108.2)
F5	261-318 (116.4-142.2)	263-318 (117.7-142.2)	237-300 (108.3-134.1)

* F-Scale associated wind speeds are $\frac{1}{4}$ fastest-mile speed (Fujita, 1971)