Tornado Damage in Happy, Texas,

May 5, 2002

A report prepared by Larry J. Tanner, P.E.

Submitted to NIST

August 19, 2002

Wind Science and Engineering Research Center Texas Tech University Lubbock, Texas

Acknowledgments

The author acknowledges National Weather Service for their assistance in the field investigation; Kishor C. Mehta, Ph.D., P.E., Director of the Wind Science and Engineering Research Center (WISE), Texas Tech University, for his technical review; and April MacDowell, Research Associate, WISE, for logistical support during the field investigation and for research for this paper. This investigation was performed under the Department of Commerce NIST/TTU Cooperative Agreement Award 70NANB8H0059.

Table of Contents

Acknowledgments	ii
Abstract	iv
List of Figures	v
Introduction	1
Main Damage Observations	
Conclusion	
References	
APPENDIX A	

Tornado Damage in Happy, Texas

May 5, 2002

Abstract

In the early evening of Sunday, May 5, 2002, the rural community of Happy, Texas, was struck by a tornado that killed two residents and damaged or destroyed numerous structures. The storm entered the city on the west side and proceeded on a circular path, exiting the southwest corner and reentering the city on the southeast portion of the city. The storm continued along an east-northeast path over farmland and struck two separate farm homes. Storm damage to site built structures varied from extensive to moderate. The most extreme damage and the deaths occurred when the storm re-entered the city and struck several manufactured homes. The National Weather Service (NWS) in concert with the Wind Science and Engineering Research Center (WISE) at Texas Tech University rated the storm a low F2 damage with wind speeds in the range of 115-130 mph (54-61 m/s).

List of Figures

Figure 1.	Tornado Path, Happy, Texas, May 5, 2002	2
Figure 2.	Tornado Path	3
Figure 3.	Tin Roof Residence, northeast corner	4
Figure 4.	First Baptist Church Storm Damage, northwest corner	4
Figure 5.	Church Education Wing, east view	5
Figure 6.	Education Wing Roof Structure	5
Figure 7.	Fujita Tornado Model	6
Figure 8.	Classic F1-F2 Residential Damage, northeast view	7
Figure 9. 1	Debris Field, indicates storm path	7
Figure 10.	Deviation of Tornado Course	8
Figure 11.	Tornado Structure	8
Figure 12.	Happy, Texas, southeast corner	9
Figure 13.	Funnel Cloud Crossing US Hwy 87, Happy, Texas 1	0
Figure 14.	Semi-tractor Trailer Overturned by Tornado 1	0
Figure 15.	Wood Frame Home, Roof Removed 1	1
Figure 16.	Debris Field 1	1
Figure 17.	Manufactured Home, anchors pulled out of ground 1	2
Figure 18.	Manufactured Home, broken tie-down 1	2
Figure 19.	Destroyed Manufactured Home 1	3
Figure 20.	Open Structure, near manufactured home with deaths 1	3
Figure 21.	Damaged Farm Home 1	4
-		

Introduction

There were two tornadoes in northern Swisher County in the South Plains of Texas on the evening of May 5, 2002. The first one developed at 6:30 pm about 5 miles west of the town of Happy, Texas. This tornado dissipated just west of town. A second tornado developed on the west edge of the Texas rural town and the National Weather Service (NWS) issued the first warning at 6:33 pm and the town tornado sirens were sounded. This second tornado entered the city and proceeded on a circular path, exiting the southwest corner and reentering the city on the southeast portion of the city. The storm continued along an east-northeast path across Interstate Hwy 27, over farmland and struck two separate farm homes 3 miles (4.8 km) east of Happy. The storm translational speed was recorded by the NWS as approximately 20 mph (8 m/s).

The NWS, in concert with the Wind Science and Engineering Research Center (WISE) at Texas Tech University, rated the storm as having low F2 damage (see Appendix A) and assigned a wind speed range of 115-130 mph (54-61 m/s). By definition, an F2 tornado represents "Significant Damage, roofs torn off frame houses; mobile homes demolished; large trees snapped or uprooted; light-object missiles generated" (Fujita, 1971). Engineering-oriented storm investigators have concluded that unzoned rural construction is markedly inferior to construction within cities that have active building code enforcement programs, and that traditional methods of housing construction evolve differently in large cities (Minor et al., 1993). The town of Happy, Texas does not have a building code. However, the cities to the north and south, Amarillo and Lubbock, have adopted and used the Uniform Building Code (UBC) for many years. According to the UBC, the design wind speed for both cities is a fastest-mile rating of 90 mph (42 m/s) (UBC, 1997). Methods for determining wind speeds for wind calculations have varied over the years. The Fujita Scale that was developed in the 1970's utilizes a fastest ¹/₄mile measurement. Fastest ¹/₄-mile speed is close to peak 3-second gust measurement for high wind speeds as used by meteorologists today. Refer to Appendix A for relation of wind speeds – fastest ¹/₄-mile to 3-second gust to fastest-mile.

The design and construction of residential and farm structures is normally based upon experience and judgment, rather than engineering calculations. Excepting the First Baptist Church and manufactured homes, which were formally engineered, all affected structures appear to fall in this category. Sound construction practices should assure that the buildings are capable of withstanding wind speeds higher than the basic wind speed, implying an overall margin of safety with respect to loading of at most 2-3. Therefore, from the proportionality of the wind loads to the square of the wind speeds, those buildings would be expected to collapse under wind speeds of 90 x $(2)^{1/2} = 127$ mph (60 m/s). The expectation would be even stronger that wind speeds corresponding to wind load three times as large as those induced by the 90 mph (i.e., 155 mph, 73 m/s) would leave no buildings standing, especially if the construction is mediocre or poor (Simiu, 1998). The Happy tornado was unique in regard to its circular path (see **Figure 1**) and the damage and deaths that resulted from the relative low wind speeds. The storm entered the town on the west, exited the southwest corner and reentered the city on the southeast portion of the city. The storm continued along an east-northeast path over farmland and struck two separate farm homes. Storm damage to site-built structures varied from extensive to moderate. The most extreme damage and the deaths occurred when the storm re-entered the city and struck several manufactured homes.



Figure 1. Tornado Path, Happy, Texas, May 5, 2002

Damage Observations

Figure 2 is an aerial view depicting the entry point of the storm into Happy. The first buildings damaged were the First Baptist Church educational building and a tin roof single-family residence approximately 150 feet south of the church. The church sanctuary experienced minor shingle damage and the northeast corner of the residence roof was damaged. However, the educational wing of the church was extensively damaged.



Photo Courtesy of NWS

Figure 2. Tornado Path

Of particular interest is the minor damage inflicted on the church sanctuary and the residence, **Figure 3**, and the extensive damage inflicted on the church educational wing, **Figure 4**. The residence suffered minor damage to the roof and porch northeast corner. The lumber debris in the foreground of **Figure 3** indicates the general direction of the storm path. Combining the assigned wind speeds of 113-130 mph (54-61 m/s) with the storm translational speed of 20 mph (9 m/s) renders a storm entry point speed of approximately 122-150 mph (58-71 m/s). The minor nature of the damage to the residence and the sanctuary therefore leads one to believe the vortex width to be quite narrow, less than 150 feet, and perhaps not even on the ground.



Figure 3. Tin Roof Residence, northeast corner



Figure 4. First Baptist Church Storm Damage, northwest corner

Somewhat anomalous is the extensive damage inflicted on the second story of the church education wing; see **Figure 5** and **Figure 6**. Several explanations can be offered for this anomaly. As previously explained for the tin roofed residence, the fastest wind speeds is assumed to be in the right front quadrant of the storm where you have the tangential velocity added to the translational velocity. In agreement to this theory, the back left quadrant would therefore be the weakest (tangential minus translational), or in this case, 93-110 mph (39-52 m/s). This would indicate that this near catastrophic failure occurred at wind speeds near the code design speeds and reflects little residual building strength.



Figure 5. Church Education Wing, east view



Figure 6. Education Wing Roof Structure

The First Baptist Church, Happy, Texas, was professionally engineered and constructed in 1965. Explanations for the building failures are numerous. It is unknown whether the level of engineering calculations included wind design. The science of wind engineering has progressed considerably since the construction of this church. In that era, it was common practice to rely upon the dead weight of building materials to resist the uplift forces produced by wind. Connections and member sizes would therefore only be designed for gravity loads. The church sanctuary was constructed of glue laminated wood arches and heavy timber decking. The education wing however was constructed of plywood sheathing nailed to long span 2x6 wood rafters, which were toenailed to steel beams by virtue of a wood nailer bolted to the top flange of the beams. **Figure 6** shows the long span of the rafters and various broken connections. Given the wind speeds, previously assumed, the roof structure could have experienced failure resulting from the reverse loading of the structural elements.

Inspection of **Figure 4** reveals the roof debris from the education wing on the west side of the building. One would normally consider the west building face in a west to east moving storm to be considered the windward face. However, the location of the debris suggests otherwise. As previously discussed, the northwest side of this tornado (backside) should have been slower than the other storm quadrants. However, tornado speeds can be modified by numerous conditions that can occur within the storm. The storm contains inflow (convergence) winds, outflow (divergence) winds and localized turbulence (gustiness). These conditions can lead to mesovortices (suction vortices), within and around the tornado edges, which form and dissipate continuously and produce higher wind speeds than the central storm vortex for its duration (Fujita, 1981). **Figure 7** shows a model illustrating Fujita's theory.



Figure 7. Fujita Tornado Model, (Fujita, 1981)

From the church, the storm veered southward producing classic F1-F2 roof damage to several homes, see **Figure 8**. The storm proceeded to destroy the school bus barn and exited the southwest corner of the town. According to Minor, "housing damage data can be used to determine the width of the tornado path" (Minor et al., 1993). **Figure 9** indicates the storm path and width with a line of debris.



Figure 8. Classic F1-F2 Residential Damage, northeast view



Figure 9. Debris Field, indicates storm path

The circuitous path taken by the Happy Tornado was probably the result of downbursts and/or microbursts near the tornado that influenced both the tornado's path and the internal structure. Fujita explains, "A downburst to the left of a traveling tornado pushes the tornado toward the right...a 'left turn tornado' occurs when a downburst is to the right of a tornado. Even a 'U-turn tornado' is seen when one or more downbursts deviate a tornado course significantly," see **Figure 10** (Fujita, 1978). He further states, "The axisymmetric structure of a tornado is destroyed when a nearby downburst or microburst intensifies the inflow air from a specific direction. Quite often, so-called 'suction vortices' (mesovortices) form where the convergence into the tornado core is the largest, see **Figure 11** (Fujita, 1978)."



Figure 10. Deviation of Tornado Course, (Fujita, 1981)



Figure 11. Tornado Structure, (Fujita, 1981)

Figure 12 indicates the path of the storm re-entering the southeast corner of the town of Happy, Texas. At this point the tornado was organized into a funnel as shown in Figure 13, a photograph taken by engineer and storm chaser Tim Marshall, as the storm crossed US Hwy 87.



Figure 12. Happy, Texas, southeast corner

Re-entering the town, the storm toppled a semi-tractor trailer and damaged or destroyed numerous automobiles, **Figure 14.** It then struck a site-built wood frame home removing its roof, **Figure 15**, and transporting the roof section approximately 150 feet (48 m). Evidence of debris generation is shown in **Figure 16**, most of which was short wood 2x members. At this point, the storm path was assessed to be 350 feet (107 m) wide. The storm proceeded to strike two manufactured homes, destroying both and killing two occupants of one. Although the age or general condition of the manufactured homes was unknown, the initial mode of failure included the removal of ground anchors on one side, **Figure 17**, and the subsequent breaking of the anchor strap on the opposite side, **Figure 18**. Both homes were rolled approximately 80 feet (24 m) and totally destroyed, **Figure 19**. Light wood frame structures near the destroyed manufactured homes were minimally damaged, **Figure 20**. Explanations of this anomaly suggest that the storm path was either quite narrow or that the manufactured homes were subject to the weak side (back left

quadrant) of the storm. The storm then crossed Interstate Hwy. 27 and damaged two farm homes 3 miles (4.8 km) east of the city, **Figure 21**.



Photograph Courtesy Tim Marshall

Figure 13. Funnel Cloud Crossing US Hwy 87, Happy, Texas



Figure 14. Semi-tractor Trailer Overturned by Tornado



Figure 15. Wood Frame Home, Roof Removed



Figure 16. Debris Field



Figure 17. Manufactured Home, anchors pulled out of ground



Figure 18. Manufactured Home, broken tie-down



Figure 19. Destroyed Manufactured Home



Figure 20. Open Structure, near manufactured home with deaths



Figure 21. Damaged Farm Home

Conclusion

The tornado that struck Happy, Texas, on May 5, 2002 was small in intensity and width and produced damage consistent with the Fujita damage scale for an F1-F2 storm. Members of the National Weather Service and an engineer from the Wind Science and Engineering Research Center of Texas Tech University conducted damage assessment and wind speed assignment. The wind speed of 115-130 mph (54-61 m/s) was consistent with damage observed.

The following conclusions are significant insofar as:

- 1. Partial destruction of site-built, wood frame structures indicates wind speeds above, but near the code design speed of 90 mph (38 m/s).
- 2. Damage to the education wing of the First Baptist Church was the result of backside winds from the tornado vortex, possibly a mesovortex or other turbulent winds. The roof failure was the result of uplift forces (negative pressures) acting upon long span rafters, lightweight decking and connections designed for gravity loads.
- 3. The storm path was indicated by a debris field of lightweight wood members and portrays a circular path, possibly the result of storm downbursts and/or microbursts.
- 4. The lack of storm damage to lightweight structures near the north side of the manufactured home, where two deaths occurred, would indicate a very narrow and weak storm, or that the manufactured home was located on the weak side (back left quadrant) of the storm. Given these storm conditions and the site investigation, failure of the home was initiated by an improperly installed anchoring system that released the home into the wind field allowing it to tumble and be destroyed.
- 5. The assignment of wind damage and speeds is enhanced by the coordination and cooperation of atmospheric scientists and engineers.

References

Fujita, T.T. (1978). *Workbook of Tornadoes and High Winds for Engineering Applications*, SMRP Research Paper No. 165, University of Chicago.

Fujita, T.T. (1981). "Tornadoes and Downbursts in the Context of Generalized Planetary Scales," *Journal of the Atmospheric Sciences, Vol. 38, No. 8.*

Minor, J.E., McDonald, J.R., & Mehta, K.C. (1993). *The Tornado: an engineering-Oriented Perspective*, NOAA Technical Memorandum NWS SR-147, Scientific Services Division, Southern Region, Fort Worth, Texas.

Phan, Long T., & Simiu, Emil. (1998). *The Fujita Tornado Intensity Scale: A Critique Based on Observations of the Jarrell Tornado of May 27, 1997*, National Institute of Standards and Technology, Technical Note 1426.

Uniform Building Code (1997). International Conference of Building Officials, Whittier, CA.

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

* F-Scale associated wind speeds are 1/4 fastest-mile speed (Fujita, 1971)