DAMAGE SURVEY OF THE TORNADOES NEAR ALTUS, OKLAHOMA ON MAY 11, 1982

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FOREWORD

The Institute for Disaster Research has studied tornado damage for 13 years. From damage and debris patterns much can be learned about near-ground tornado wind fields. The two tornadoes that struck near Altus, Oklahoma provided still another opportunity to study the effects of tornadoes on structures. Initial reports of damage suggested that there was only one tornado path at Altus. After corroborating with the National Severe Storms Laboratory Chase Team and after examining the damage paths, the two separate tornadoes were identified. The tornado that passed through the Altus Air Force Base was of particular interest, because it affected buildings that had received significant degrees of engineering attention in their design.

1. INTRODUCTION

On the afternoon of May l1, 1982, several tornadoes touched down in southwestern Oklahoma. One of the tornadoes struck the East Side of the city of Altus and traveled three miles in a northeasterly direction through the Altus Air Force Base, causing extensive damage (Figure 1). A second tornado touched down northeast of the Air Base just west of the Friendship community and traveled in a northerly direction at least twelve miles (Figure 2). The next day, a windstorm damage investigation team from the Institute for Disaster Research at Texas Tech University traveled to Altus, Oklahoma to document and evaluate the damage. The objectives of the damage documentation effort were:

1) To collect and evaluate data on the performance of buildings damaged by the to tornado.

2) To define the damage path and identify gradations of damage within the path using the F-scale rating system.

3) To document tornado-generated missiles.

Figure 1. View looking west of the tornado that Struck the Altus Air Force Base. Photograph Courtesy of Dr. Howard Bluestein, OU-NSSL Severe Storm Intercept Project.

Figure 2. View looking northwest of second tornado (multi-vortex) near Friendship, Oklahoma. Photograph courtesy of Dr. Howard Bluestein, OU-NSSL Severe Storm Intercept Project.

The investigation team spent two days inspecting the damage. Members of the team included an engineer, a meteorologist, and an undergraduate student in civil engineering. The purpose of this report is to present preliminary findings based on data gathered from the damage.

2. METEOROLOGICAL SUMMARY

On the morning of May 11, 1982 there was a surface low-pressure system in western Kansas and another located in northeastern New Mexico. As the day progressed, the low-pressure systems remained relatively stationary and a dryline developed in eastern New Mexico. The dryline demarcated dry, stable air to the west from moist, unstable air to the east. By mid-afternoon, the leading edge of the dryline had moved eastward into West Texas and several thunderstorms developed in the moist air along and to the east of the boundary. By 6:00 p.m., the most severe thunderstorms were located in the vicinity of the dryline bulge and extended northeastward into southwestern Oklahoma (Figure 3). Within the next few hours, a total of twenty-seven tornadoes were reported in this area (Storm Data, 1982). Most of the tornadoes occurred in open country and damage was minimal. However, the two tornadoes near Altus, Oklahoma caused extensive damage. A sequence of significant severe weather events in western Oklahoma leading through the tornadoes near Altus is shown in Table 1 in the Appendix.

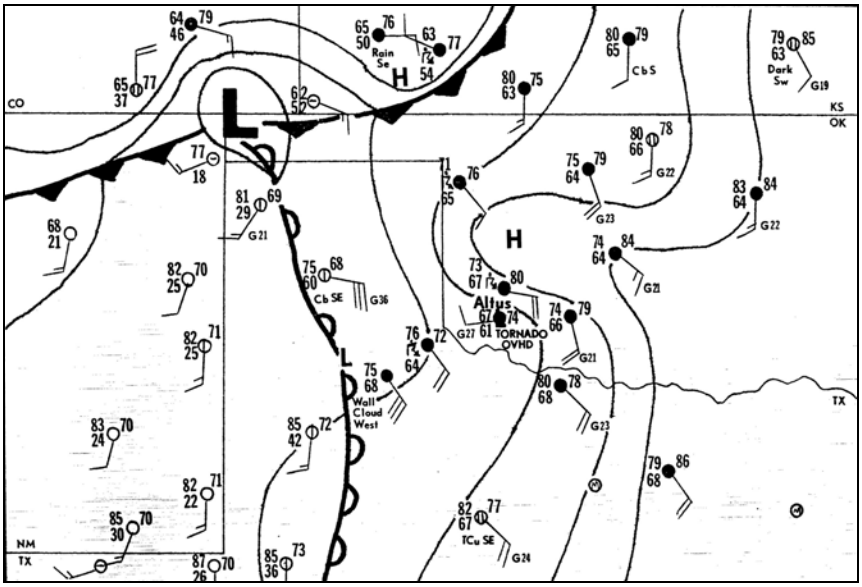

Figure 3. Surface analysis at 6 p.m. (CDT) on May 11, 1982. For each station model, the temperature (degrees F) is the upper left number, dewpoint (degrees F) is the lower left, altimeter (inches) is upper right and wind speed is ten miles per hour for each full barb. Cold front depicted by line of solid triangles. Dryline depicted by open scalloped line.

3. CHARACTERISTICS OF THE TORNADO PATHS

The first tornado touched down on the east side of Altus (Figure 4). There was only minor damage to trees, fences, and streetlights until the storm entered the Air Force Base. The tornado intensified and traveled northeastward from the main gate, across the center of the base and lifted just east of the main runway. Within a few minutes after the first tornado, a larger tornado touched down northeast of the Air Force Base near the community of Friendship. The tornado traveled northward for twelve miles through the countryside damaging rural homes and trees. Two people were killed by flying debris two miles west of Friendship as they were heading for an outdoor storm cellar. A 138 KV transmission line owned by Public Service of Oklahoma was downed as the tornado crossed Route 19, 3.5 miles east of Blair. F-scale classifications were assigned to rural building damage. Since no engineered structures were in the path of the Friendship tornado, wind speed estimates were not attempted. The characteristics of both tornadoes are listed in Table 2 in the Appendix.

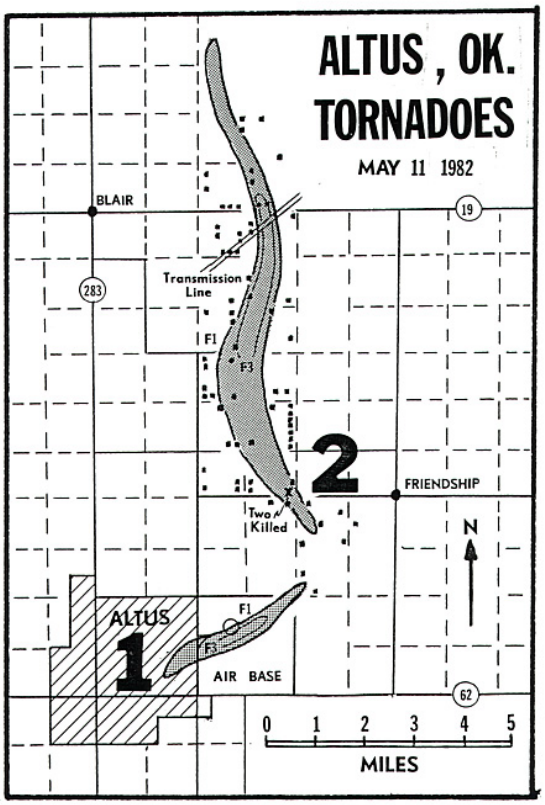

Figure 4. Damage path of the Altus tornado and Friendship tornado (shaded areas). Small squares Indicate houses. F-scale numbers also are shown.

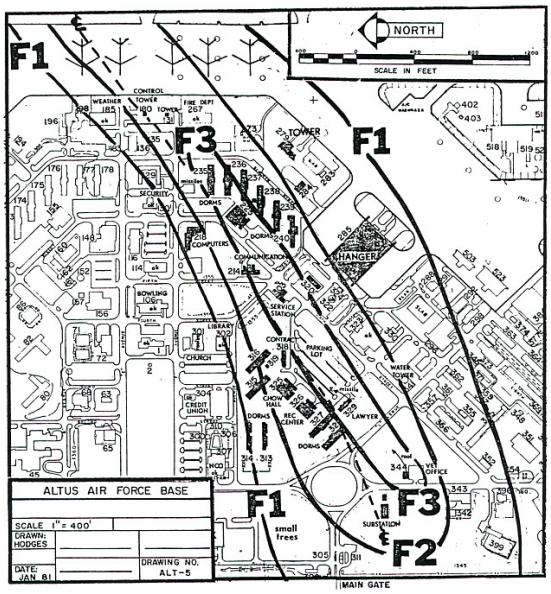

Figure 5. Detailed tornado damage path through Altus Air Force Base. Gradations in damage are depicted by F-scale.

4. ALTUS AIR FORCE BASE

The initial survey revealed that the damage path extended from the main gate across the center of the base and ended just east of the main (north-south) runway (Figure 5). The damage produced by this tornado was of great interest to the storm study team because it provided an opportunity to study the effects of tornadic winds on buildings that had received various degrees of engineering attention in their design. The storm also presented a unique opportunity to compare wind speed estimates from appearance of damage with wind speeds obtained from structural analysis of damaged building components.

F-scale ratings (Fujita, 1971) were assigned to each building examined by the storm study team based on appearance of damage and the word description associated with each F-scale classification. Care was taken not to be influenced by structural features or degrees of engineering attention. Later after all F-scale assignments had been made, independent wind speed calculations were made based on structural analysis using load and resistance statistics (Ref. Marshall, et al. 1983).

The damage path through the Altus Air Force Base shown in Figure 5 was assembled using F-scale criteria. Buildings which sustained F1 damage or greater are shaded in Figure 5. Six buildings were heavily damaged (F3), eleven had moderate damage (F2), and seven had light damage (Fl). From analysis of fallen trees and debris trajectories, the centerline of the tornado appeared to be parallel to the northern periphery of the F3 damage track. The individual performances of buildings which sustained the heaviest damage are discussed below. A rational for the assignment of the F-scale rating also is given.

4.1 Veterinary Clinic (Building 344)

The veterinary clinic is a reinforced concrete masonry building with a flat timber roof (Figure 6). It was located about 200 feet to the right of the tornado center. As the tornado passed, portions of the roof on the windward (south) side were uplifted and transported as far as a hundred feet toward the east. The roof joists were toenailed to a 2x8 plate anchored to a bond beam at the top of the wall. The bond beam was reinforced with two #5 bars. As the roof lifted, horizontal cracks formed in the mortar joint just below the bond beam. These cracks were observed around the perimeter of the building. Based on the loss of roof and minimal damage to the reinforced concrete block walls, damage to the building appears to be upper F2 or lower F3.

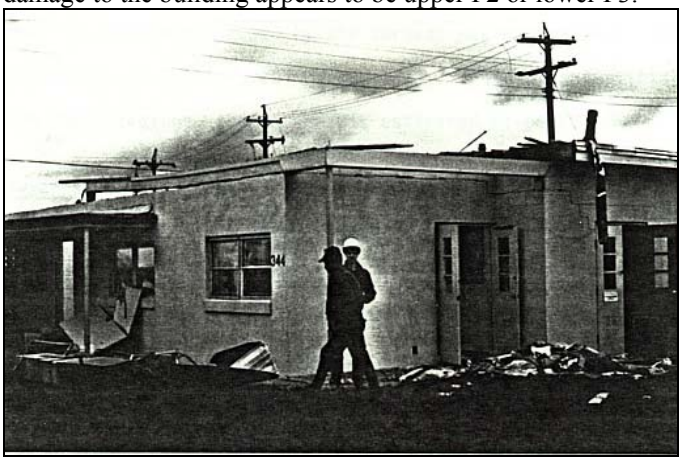

Figure 6. Southeast elevation view of the Veterinary Clinic. The cracks in the mortar joint below the bond beam occurred as the roof was uplifted.

4.2 Dormitories (Buildings 315, 316, 327 and 328)

These three-story dormitories have reinforced concrete frames with non-loadbearing brick walls (Figure 7). Each building is oriented in a northwest to southeast direction and is located just left of the tornado centerline. The longest side of each building was normal to the strongest tornadic winds. Most of the damage caused by the tornado was superficial with some broken windows and loss of roofing material. Based on superficial damage to the buildings, the damage was estimated to be F2.

Figure 7. Windward side of dormitory building #315. The steel-reinforced concrete structure had non-loadbearing masonry walls. Damage was limited to the roof covering and windows.

4.3 Base Lawyer's Office (Building 329)

The base lawyer's office is a single-story concrete masonry building and was 100 feet to the right of the tornado centerline. As the tornado passed, the window panels on the back wall failed inward, the timber roof was uplifted, and the front wall fell outward (Figure 8). The top course of each wall was a bond beam. Each bond beam was reinforced with two #5 bars. The bond beam, located on the back wall, traveled in a northeasterly direction nearly 200 feet before striking a pickup and a car (Figure 9). Also, a 12-foot long timber missile sliced through four CMU

blocks on the back wall. Based on the roof damage and missile present, the damage was estimated at upper F2 to lower F3.

Figure 8. Front CMU wall of lawyers office fell outward and roof was uplifted exposing the inner steel-framed structure.

Figure 9. Concrete masonry bond beam missile traveled from the lawyers office northeastward approximately 200 feet before striking these vehicles.

4.4 Dining Hall (Building 325)

The dining hall is a single story masonry building with a timber roof. The center of the tornado passed 200 feet to the south of the building. Roof damage was observed along the entire length of the windward (north) wall (Figure l0). A closer view of the damage to the cafeteria roof is shown in Figure 11. The roof consisted of 2x 10 inch wooden joists spaced at 12 inches on center. The joists were secured with 10d nails that were toenailed to a wooden plate at the top of the wall. As the tornado passed, part of the roof, including the roof joists, was removed and one precast concrete bond beam was lifted up and slightly displaced. Based on the damage to the roof, the damage was estimated to be F2.

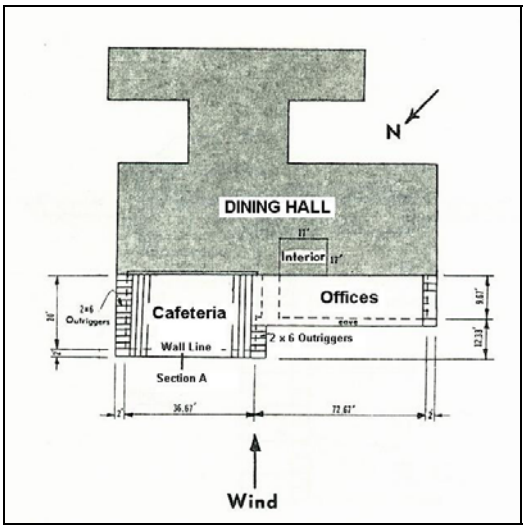

Figure 10. Roof plan diagram of the dining hall. The northwest section of this roof was uplifted (not shaded). The roof was relatively flat and composed of wooden joists supported by steel beams and masonry walls.

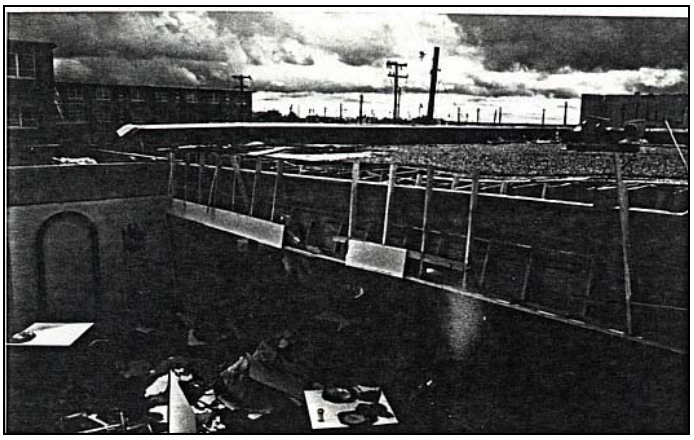

Figure 11. Flat roof section removed from dining hall. Roof was built-up type supported by wooden joists that spanned between steel I-beams and perimeter masonry walls.

4.5 Recreation (Building 326)

The Recreation Building is adjacent to the Dining Hall and similarly constructed. It is a single story masonry structure with a flat timber roof (Figure 12). Most of the damage occurred at the northwest corner of the building next to the windward side. A portion of the roof was uplifted and window glass was blown inward (Figure 13). The roof joists remained in place but the wood decking was removed. An exterior metal door in the windward wall was damaged by an impact of several timber missiles. Based on the damage to the roof corner and the presence of the missile, the damage was rated F2. Trees in the area sustained light damage and some utility poles were snapped near the ground. However, none of the utility poles were transported by the winds.

Figure 11. Roof corner was removed on recreation building. Roof was built-up type supported by wooden joists that spanned between steel I-beams and perimeter masonry walls.

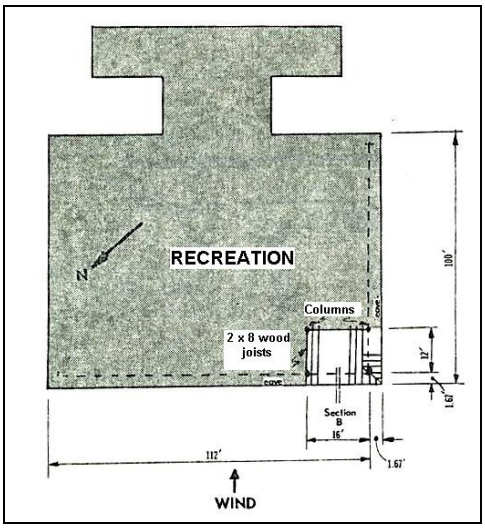

Figure 13. Roof plan diagram of the recreation building. The northwest corner of this roof was uplifted (not shaded). The roof was relatively flat and composed of wooden joists supported by steel beams and masonry walls.

4.6 Contracts Office (Building 318)

The Contracts Office has masonry walls and a mansard-type timber roof (Figure 14). It was located just left of the tornado centerline. Damage to the building was superficial with broken windows and damage to its fascia from impact of small timber missiles. Several cars in a nearby parking lot were damaged by flying roof gravel, other small missiles and hail. Windows broke in some cars and allowed roof gravel and mud to collect inside. Two compact vehicles overturned but most of the cars remained in place. Based on superficial damage to the building, overturned cars in the parking lot and the observed missiles, the damage was rated F2.

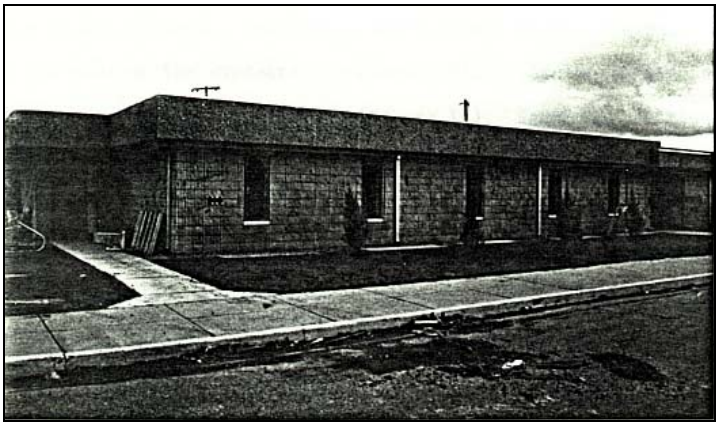

Figure 14. Front elevation view of the Contracts office building. This building only had superficial damage and was just left of the tornado center.

4.7 Aircraft Hangar (Building 285)

A large hangar 500 feet wide by 600 feet long and 80 feet tall was damaged by the tornado. The damage was confined to the siding, doors and roof on the windward (southwest) side. As the tornado passed, the hangar doors were blown inward (Figure 15). Each door section is 65 feet high and 20 feet wide. The doors are suspended from the top of the hangar and are guided on tracks at the bottom. A closer view of the hangar doors revealed that the lower edge of the center door was pushed about four feet inward. The hangar was approximately 600 feet to the right of the tornado centerline, on the periphery of the tornadic winds. The roof is constructed with 30 in. wide by 8-ft long sheets of 18 gage metal deck. The deck is 1.5 in. deep and has ribs spaced 6 in. apart. One-quarter inch diameter spot welds at the ends of each rib attached the deck to the roof framing system. Several of the sheets were uplifted and then fell back into the building.

Figure 15. Large hangar door buckled inward from wind.

Asbestos siding was removed from portions of the walls at the corners. The siding was removed after it cracked and allowed the anchor bolt to slip through the crack. Based on damage to the hangar doors, the partial roof uplift and loss of siding at wall corners, the damage was rated Fl.

4.8 Communications Building (214)

The Communications Building is a single story concrete block building with a lightweight concrete roof. The building has a long, rectangular shape and is oriented in a north-south direction (Figure 16). As the tornado passed by, roof sections on the south half of the building were uplifted whereas the northernmost half of the roof remained in place. This observation supports the contention that the center of the tornado passed directly over the building. The roof consists of a 2-in. thick perlite (lightweight) concrete slab poured over a fabric-backed wire mesh. The mesh is laid in 8-ft wide strips. It is secured to the steel joists with twisted galvanized wire. The open web steel joists are spaced 30 in. on center and are anchored to a bond beam with two half-inch diameter bolts. The somewhat unusual construction of the roof is the result of the building being designed to resist blast. As the tornado passed by, the twisted galvanized wires failed and the perlite slabs were lifted and rolled off the roof (Figure 17), but the steel joists remained in place. Based on damage to the roof and the surroundings, the damage was assigned a rating of F-3.

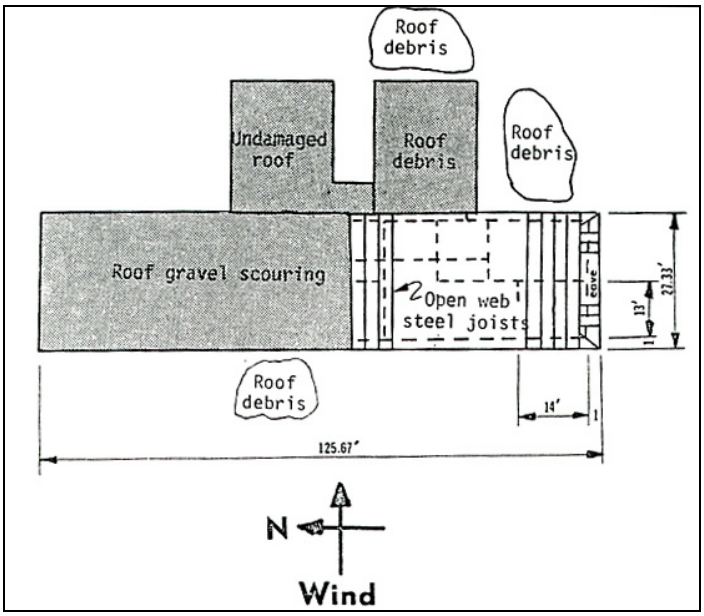

Figure 16. Roof plan diagram of the Communications Building. The damaged area of the roof is not shaded. Flat roof was comprised of lightweight concrete deck that was tied to open web steel joists.

Figure 17. Lightweight concrete roof rolled off Communications building. The reinforcing mesh in the roof slab was secured with small wire twisted to open web steel joists.

4.9 Barracks (Buildings 235-240)

A series of five two-story wooden barracks were heavily damaged by the tornado. Sections of the roofs were removed and second story walls collapsed (Figure 18). Not all the roofs failed in the same manner. Some of the roof failures were attributed to anchorage of the roof to the wide. Roof joists that were toenailed to plates on top of the walls pulled loose. In other cases, the wood joists split horizontally along their entire length. When the roof joists were removed, the top of the walls were left unsupported and in many cases the walls collapsed. The damage was estimated to be F2 or F3 based on damage to the wooden roof system.

Figure 18. Removal of roof and portion of second story exterior walls on wooden barracks. This damage was rated F-3 on the Fujita scale.

4.10 C-5 Galaxy Aircraft

Two C-5 Galaxy aircraft and one C-141 sustained major damage while four C-5s had minor damage. The aircraft were parked in a north-south row facing west before the tornado (Ref. Fig. 5). As the tornado passed over the aircraft, one C-5 Galaxy pivoted 90 degrees toward the south (Figure 19). The nose of the aircraft came in contact with the wing of another. The aircraft that pivoted was located on the northern (left) periphery of the tornado. Specifications of the C-5 Galaxy aircraft are listed in Table 3 in the Appendix.

Figure 19. Damage to the nose of a C-5 aircraft. The aircraft pivoted 90 degrees and struck the wing of an adjacent C-5 as the tornado passed.

4.11 Parachute Drying Tower (Building 279)

The Parachute Drying Tower was located on the right side of the tornado path approximately 650 feet from the tornado center (Figure 20). The rectangular tower measured 28'-6"x15'-6" in plan and was 62'-4" high. It was anchored to concrete footings with four 5/8" diameter A307 anchor bolts at each corner. As the tornado passed, the tower pivoted about a line through the two corner columns on the leeward (northeast) side of the tower (Figure 21) and fell toward the northeast. The anchor bolts failed in tension. Based on the collapse of the tall, rather fragile tower, the damage was rated Fl.

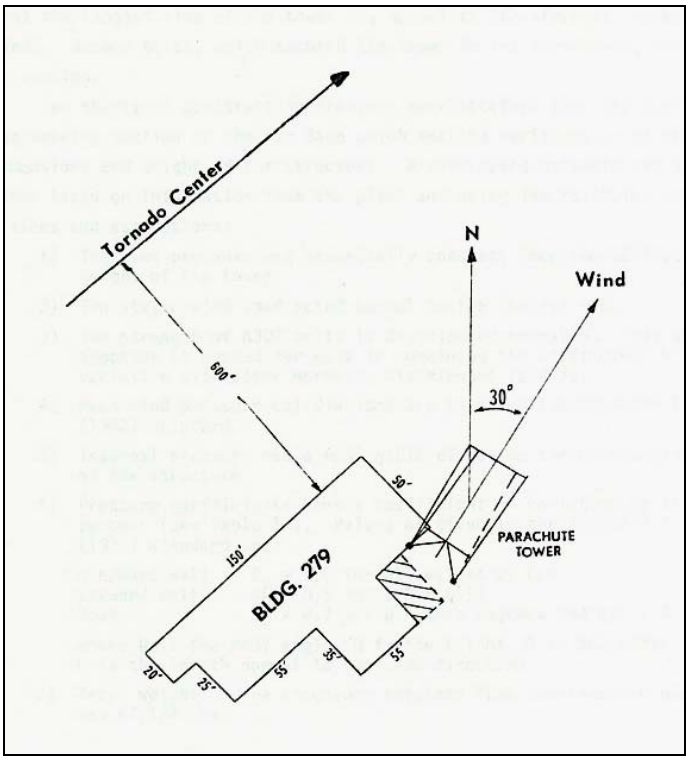

Figure 20. Plan view diagram of the parachute drying tower at Building 279. The tower toppled to the northeast as the tornado passed by to the northwest.

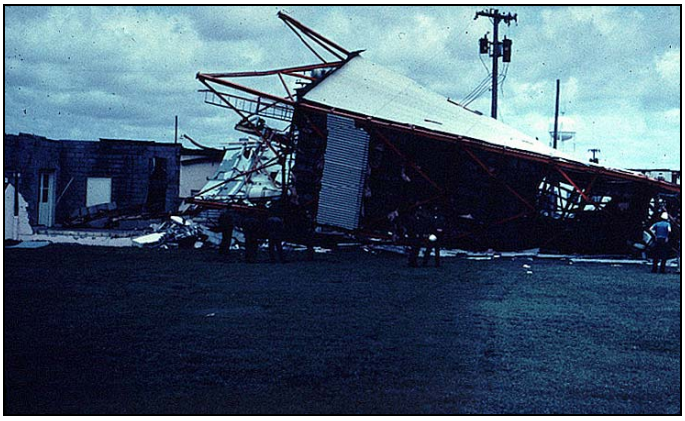

Figure 21. Overturned parachute drying tower. Failure initiated when anchor bolts securing the two corner columns had failed in tension.

5. WIND SPEED CALCULATIONS

The maximum intensity of the damage at Altus Air Force Base, based on appearance of damage (F-scale) was rated F3. Later, Marshall (1983) calculated wind speeds based on structural analysis of damaged structural components. Construction plans were obtained for the Parachute Drying Tower, Dining Hall, Recreation Building and Communications Building. From these plans, Marshall calculated expected wind speeds to produce the observed damage and confidence limits using load and resistance statistics. A comparison of wind speeds estimated from F-scale descriptions and wind speeds based on structural analysis is shown in Table 4 in the Appendix. Results from the Communication Building are not included in Table 4 because the exact spacing of the wire ties that anchor the roof slab to the joists is unknown.

The failure modes for the structural analyses were primarily due to connection and anchorage failures. The Parachute Tower overturned when anchor bolts in two of the corner columns failed in tension. Roof failure at the Dining Hall and Recreation buildings occurred when the wood joists, which were toenailed to the plate at the top of the wall, uplifted. Uncertainties in the pullout strength of toenailed connections are reflected in the rather wide confidence bands. In the case of the Parachute Tower, structural calculations predict an expected value that is 25

percent greater than the mean F1 wind speed value. In the case of the Dining Hall and Recreation buildings the wind speed based on the structural calculations are less than the mean F-scale wind speeds by, at most, 13 percent. Thus, in these cases the differences in calculated wind speeds and wind speeds based on F-scale ratings is not significant. Other cases, especially at higher wind speeds may show more significant differences. Based on a combination of F-scale ratings and structural calculations, it appears that wind speeds in the Altus tornado were less than 150 mph.

6. CONCLUSIONS

The following conclusions were made from assessing damage at Altus Air Force Base:

1. Based on both appearance of damage and structural calculations, estimated wind speeds probably did not exceed 150 mph at roof height.

2. Engineered structures performed well in the tornadic winds.

3. The Parachute Tower provided an ideal case for making wind speed calculations since it was a clean, freestanding structure.

4. Correlation between wind speeds estimated from assignment of an F-scale rating and structural calculations did not agree, but the differences are not large.

7. ACKNOWLEDGEMENTS

The cooperation of personnel at Altus Air Force Base, Altus, Oklahoma, in coordinating this damage survey is gratefully acknowledged. The assistance of the disaster team on the base helped our storm study team acquire the necessary information for this study. Also, the assistance of Captain A.R. Walker of the Airforce Base Weather Station and Captain Walter L. Garner of the Civil Engineering Department is appreciated. Funds for this tornado damage documentation effort were provided by the U.S. Nuclear Regulatory Commission Contract No. NRC-04-76-345. Robert F. Abbey, Jr., serves as contract monitor on the project.

8. REFERENCES

Fujita, T.T., 1971: "Proposed Characterization of Tornadoes and Hurricanes by Area and Intensity," SMRP Research Report 91, University of Chicago, 15 p.

Marshall, T.P., J.R. McDonald and K.C. Mehta, 1983: "Utilization of Load and Resistance Statistics in a Wind Speed Assessment," Institute for Disaster Research, Texas Tech University, Lubbock, Texas, 91 p.

National Oceanic and Atmospheric Administration (NOAA), 1981: Storm Data, May 1982.

TABLE 1

OKLAHOMA CITY SEVERE STORM SUMMARY FOR MAY 11, 1982

Courtesy of the Oklahoma City National Weather Service

Local time (CDT)	REPORT
4:00 pm	Baseball-size hail reported in ElDorado in southwest Jackson County.
4:17	Tornado watch issued for western Oklahoma.
4:49	Jackson County sheriff reported funnel cloud ten miles southwest of Altus.
5:00	Tornado watch valid.
5:03	Oklahoma Highway Patrol at Altus reported tornadoes west of Altus and near Creta.
5:18	Oklahoma Highway Patrol at Altus reported tornado seven miles west of Altus.
5:24	NSSL Chase Team reported tornado 8 miles south of Blair in Jackson County.
5:35	Oklahoma Highway Patrol at Altus reported tornado six miles west of Blair in Jackson County and tennis-ball size hail in Altus.
5:38	Oklahoma Highway Patrol at Altus reported tornado 1.5 miles south of Altus.
5:59	Oklahoma Highway Patrol at Clinton reported tornado 11 miles southwest of Cheyenne.
6:00	Oklahoma Highway Patrol at Altus reported tornado at the Air Base. Seven buildings extensively damaged or destroyed.
6:10	Oklahoma Highway Patrol at Clinton reported tornado five miles west of Cheyenne moving northeast.
6:58	Oklahoma Highway Patrol at Clinton reported numerous funnel clouds in Roger Mills County.
6:59	Oklahoma Highway Patrol at Altus reported tornado 1.5 miles south of Lone Wolf in Kiowa County.
7:31	Amateur radio spotters reported a tornado four miles west-southwest of Arnett in Ellis County.
7:46	Oklahoma Highway Patrol at Altus reported a tornado two miles north of Sentinel in southern Washita County.
8:18	Sayre Police Department reported a tornado seven miles southeast of Sayre in Beckham County.
8:42	Oklahoma Highway Patrol at Clinton reported a tornado ten miles west of Clinton.
10:55	Madill Police Department reported golfball-size hail at Texoma Lake around 10:15 pm.

TABLE 2
CHARACTERISTICS OF THE ALTUS AND FRIENDSHIP, OK TORNADOES

Tornado Sequence (CST)	Altus	Friendship
Tornado began	5:48 pm	6:02 pm
Tornado entered air base	5:51 pm	n/a
Tornado over weather station	5:55 pm	n/a
Tornado dissipated	6:00 pm	6:22 pm
Path Length		
Total length	3.5 miles	12.0 miles
F-3 damage	.5 mile	3.5 miles
F-2 damage	1.0 mile	6.0 miles
F-1 damage	2.0 miles	10.0 miles
Path Width		
F-3 damage	.06 mile	.33 mile
F-2 damage	.017 mile	.50 mile
F-1 damage	.29 mile	.75 mile
Direction of Travel	E-NE	N
Average Translational speed	7.5 mph	25 mph
Circulation	single vortex	multi-vortex

TABLE 3

C-5 AIRCRAFT SPECIFICATIONS

Weight	
Without cargo and fuel	335,000 lbs
Without cargo, fully fueled	635,000 lbs
Normal operating weight	635,850 lbs
Maximum gross weight	769,000 lbs
Dimensions	
Wing span	223 feet
Length	248 feet
Stabilizer height	65 feet
Stabilizer span	69 feet
Fuel capacity	49,000 gallons
Performance	
Takeoff speed at 712,500 lbs	160 mph
Landing speed at 400,000 lbs	131 mph

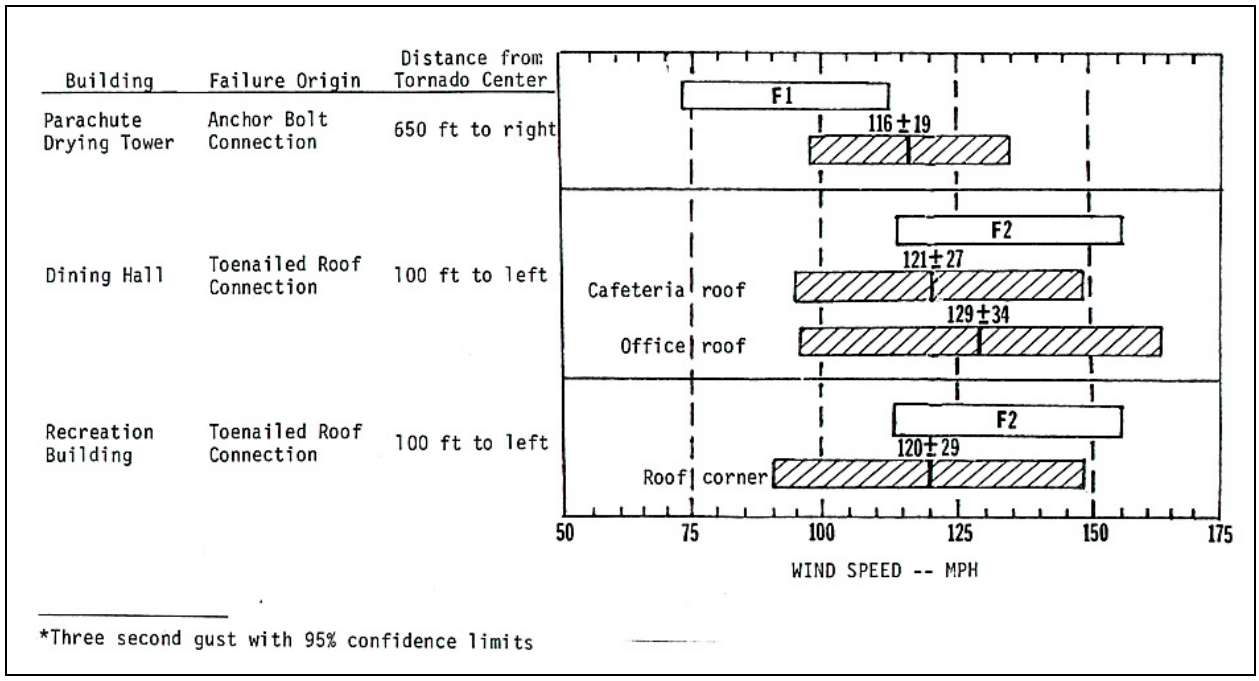

Table 4. Summary of wind speed estimates in the Altus, Oklahoma tornado (after Marshall, 1983).