Online Summary

Damage from the 20 May 2013 Tornado in Moore, OK

(Image Courtesy of http://www.huffingtonpost.com/2013/05/20/moore-tornado-2013-oklahoma_n_3308904.html#slide=2477217)

University of Florida Wind Hazard Damage Assessment Team

PI: David O. Prevatt, Ph.D., PE
dprev@ce.ufl.edu

Contributing Authors:
  David Roueche
  Austin Thompson
  Jeandona Doreste

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Executive Summary

Nearly two years to the day after Joplin, MO is hit by the EF-4 tornado, Moore, OK is impacted by another powerful tornado resulting in substantial damage to houses, schools, and several fatalities. The National Weather Service classified the tornado as an EF-5 and parts of the damage path were mapped at nearly 2 miles wide. Statistically, such powerful tornadoes have very low probability of occurrences, but by cruel twist of fate, Moore, OK has seen three powerful and destructive tornadoes since 1999 in nearly the same locations, with similar heart-wrenching results. From this tragedy, a unique opportunity may present itself for us to learn from our past rebuilding efforts, to understand whether our structures had improved over time, and to improve knowledge to prevent/reduce tornado losses.

This report was prepared from online sources by University of Florida civil engineering students in Prof. David O. Prevatt’s Research Group. It is part of their learning in forensic engineering and post-disaster damage investigation. Students were tasked to gather information from online sources and collate information on the tornado (from the National Weather Service, storm chaser Twitter feeds), injuries and fatalities (from media reports) and on structures (from the US Census Bureau and building code websites).

Researchers at the University of Florida and elsewhere will continue to document tornado outbreaks as they occur, and in parallel our research to understand and quantify the strength of tornado loads and their interaction with vulnerable wood-framed structures is continuing. It is our thesis, that engineering solutions can be found to improve the tornado-resistance of houses. These solutions come at a price, yet to be determined, once scientists have a better idea of the loads, and society determines what risks are acceptable. Stronger buildings can be built quite economically today that would mitigate structural damage and provide better life safety protection – it is up to communities and their leaders to decide whether they wish to pursue such resilient and sustainable approaches or whether to continue with the status quo.

Please visit our website, for further information http://windhazard.davidoprevatt.com. Background information and our previous damage survey blogs can be found on Dr. Prevatt’s webpage, www.davidoprevatt.com, including the Tuscaloosa Tornado Damage Survey Report. A list of helpful references is included at the end of this report.

Your questions and comments on any aspects of our work are most welcome. Please direct your enquiries to NSF Graduate Research Fellow, and PhD Graduate Student, Mr. David B. Roueche, who can be reached at david.roueche@ufl.edu.

About the Wind Hazard Damage Assessment Team

The Wind Hazard Damage Assessment Team was created through support from the NSF Award #1150975. Its mission is to train university students interested in building construction, engineering and architecture in the forensic engineering and techniques for post-hazard damage surveys and data collection. The team has surveyed damage after several Florida tornadoes and continuously monitors the prevalence of tornadoes worldwide. Ultimately the Team hopes to inspire upcoming engineers and building professionals in hopes to change the paradigm of widespread catastrophic damage to houses in tornadoes. Mr. Jeandona (JD) Doreste, is a civil engineering undergraduate student at UF and Webmaster of the Wind Hazard Damage Assessment Team site. JD is actively recruiting other UF students to join the team, and he can be reached at jdoreste1@ufl.edu.
PREDICTION OF WEATHER

Initial expectations for tornado risk on May 20th were significant (Figure 1), with the Storm Prediction Center tornado outlook showing a large area with the probability of tornado genesis in Central Oklahoma and Northern Arkansas.

![Figure 1: Tornado Probability for May 20, 2013 as Issued by the NWS SPC at 12:20 PM UTC on Same Day](http://www.spc.noaa.gov/products/outlook/archive/2013/day1otlk_20130520_1300.html)

TWEETS

Storm chasers were also expecting a significant outbreak and many different teams had gathered in this region, providing up-to-date predictions on Twitter as the storms began to unfold.

Johnny Kelly @stormchaser4850 20 May
A significant outbreak of tornadoes is expected to unfold for a 3rd day including parts of TX, OK, MO, AR pic.twitter.com/47qUDzOb4j

28storms.com @28storms 20 May
RT @NWSNorman: Increasing concern for more tornadoes today, esp along and south of I-44! spread the word. #okwx

TIMING OF TORNADO

The timeline of the tornado as it formed and impacted the city of Moore, OK is given below. An illustration of the timing of the tornado impact is shown in Figure 2.

1:54 PM – Spinning Cloud Forms south of Tuttle, OK
2:30 PM – Hook spins up west of Newcastle, OK
2:40 PM – CDT: A tornado warning was issued that included Moore, Okla.
2:46 PM – EF3 Tornado sets down west of Newcastle, OK
3:00 PM – EF4 Tornado hits Newcastle, OK
3:01 PM – Tornado Emergency issued for Moore
3:24 PM – EF4/EF5 Tornado hits Moore, OK
3:43 PM – First images of destruction surface on The Weather Channel
4:02 PM – NWS Tulsa confirmed a tornado near Avant moving northeast at 45 mph.
6:07 PM – Storm chasers Jim Cantore, Mike Bettes and the Tornado Hunt team first arrive in the damaged areas; comparisons immediately drawn to Joplin, Mo. tornado of 22 May 2011
7:16 PM – Death toll announced at 37 by Associated Press, via Twitter

Figure 2: Timing of Tornado Impact to Moore, OK
(Source: https://pbs.twimg.com/media/BKxI3TACYAA3O7D.jpg)
The NWS survey teams confirmed at least 18 tornadoes occurred in the 20 May 2013 tornado outbreak, the first occurring in McClain County at 2:46 PM UTC and the last reported at 1:50 AM the following day in Le Flore County. The most dramatic damage seen was that of the tornado traveling through Moore, OK. Preliminary reports of the damage indicated an EF4 damage rating would be assigned, but after the damage assessments by the local NWS survey teams were completed the afternoon of May 21st, this rating was upgraded to an EF5, with peak estimated wind speeds of 200-210 mph. The maximum path width of the tornado was estimated to be 1.3 miles and the approximate length was 17 miles, with the tornado appearing to intensify right as it reached the heavily populated regions of southern Moore, OK. According to the Norman, OK NWS office, the EF5 rating was given due to damage observed at Briarwood Elementary school. Using the provisions of the EF scale, a Degree of Damage of 10 is given when “Total destruction of a large section of building or entire building” occurs, corresponding to a wind speed between 152 and 203 mph with an expected value of 176 mph. The elementary school in question is shown in Figure 4, with the photo on the right given as evidence of the total destruction necessary for that Degree of Damage. At this time, 24 fatalities and over 240 injuries are reported.
PREVIOUS TORNADOES IN MOORE, OK

**MAY 3 1999:** During evening rush hour traffic Moore, Oklahoma was struck by a devastating F5 tornado that resulted in 42 deaths and over 800 injuries (Brown et al. 2002). The majority of the damaged buildings were one and two-story residential structures built on concrete slab foundations. Property damage was well over $1 billion dollars. FEMA sent a Building Performance Assessment Team (BPAT) who produced a damage survey and report, [http://www.fema.gov/library/viewRecord.do?id=1423](http://www.fema.gov/library/viewRecord.do?id=1423). Another damage survey report was produced by Marshall (2002). After this event, 6,016 Safe Rooms were built with the help of the $12 million Oklahoma SafeRoom initiative.

**MAY 8 2003:** At 4:10 CST pm a tornado formed rapidly near Santa Fe Avenue and NW 5th Street in Moore, and quickly strengthened to F3 intensity as it moved east-northeast through Moore - paralleling the path of the May 3, 1999 F5 tornado, but tracking 1/4 mile or less farther south. The most intense damage in Moore (F3) occurred just W of I-35 and north of 12th Street, where several businesses were leveled ([http://www.srh.noaa.gov/oun/?n=tornadodata-ok-violent](http://www.srh.noaa.gov/oun/?n=tornadodata-ok-violent)).
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Engineering School of Sustainable Infrastructure and Environment  
University of Florida  
May 21, 2013

Figure 5: Tornado Tracks from the 1999 F5 (red), 2003 F4 (blue), and 2013 F4/F5 (green) Tornadoes  

BUILDING CONSTRUCTION IN MOORE, OK
Moore, OK has a population of approximately 56,315 persons, living in 21,000 homes  
(http://quickfacts.census.gov/qfd/states/40/4049200.html). Also affected was the town of Newcastle, population is 7,800  
(http://quickfacts.census.gov/qfd/states/40/4051150.html).

75% of the homes in Moore were built before 2000 (i.e. more than 13 years old). The complete distribution of home ages is illustrated in Figure 6.

Figure 6: Distribution of Home Age in Moore, OK
In their press release, the Federal Alliance for Safe Homes stated that most tornado damage occurs below EF4/EF5 level, so minor investments in enhanced building or rebuilding techniques can make a major improvement in a home's resistance to tornado forces. The National Climatic Data Center estimates that 77 percent of U.S. tornadoes are in the EF0 to EF1 range and 95 percent have wind speeds less than EF3 intensity. A recent cost study revealed that using an average of $0.50 per square foot or $1,000 in metal connectors installed from a home's roof to its foundation can upgrade a home's ability to withstand wind uplift from an EF0 to an EF2 tornado.

Table 1: Adoption of Codes in Impacted Towns

<table>
<thead>
<tr>
<th>Codes Adopted</th>
<th>Town</th>
<th>Moore, OK</th>
<th>Newcastle, OK</th>
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<tbody>
<tr>
<td>2009 International Building Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2003 International Energy Conservation Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2009 International Existing Building Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2009 International Fire Code</td>
<td>x</td>
<td></td>
<td>x</td>
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<tr>
<td>2009 International Fuel Gas Code</td>
<td>x</td>
<td></td>
<td>x</td>
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<tr>
<td>2009 International Mechanical Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2009 International Plumbing Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2006 International Property Maintenance Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2009 International Electrical Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2009 International Residential Code</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Source(s): [http://www.iccsafe.org/gr/Pages/OK.aspx](http://www.iccsafe.org/gr/Pages/OK.aspx)  

OBSERVED DAMAGE

Although detailed information is not yet known, reports obtained from local news agencies and social media have indicated heavy damage to at least two elementary schools, a large hospital, a movie theater and a number of smaller commercial buildings. Figure 7 shows the location of key structures impacted by the tornado in relation to the approximate tornado path.
Some of the heaviest damage was observed at the two elementary schools, Briarwood Elementary (built 1985) and Plaza Towers Elementary (built 1966), and the surrounding areas. Before and after photos of these two schools are shown in Figures 8. It is not known at this time what the exact structural designs for these schools were but it has been reported that neither school had tornado shelters (Source: [http://www.usatoday.com/story/news/2013/05/22/safety-experts-oklahoma-school-tornado-shelter-](http://www.usatoday.com/story/news/2013/05/22/safety-experts-oklahoma-school-tornado-shelter-).
preparedness/2349761/). Similar schools were damaged in the 1999 F5 tornado however and are discussed at length in the FEMA 342 report referenced at the end of this document.


(a) Plaza Towers (before)  
(b) Plaza Towers (after)


(c) Briarwood (before)  
(d) Briarwood (after)


In addition to the schools damaged, significant damage was also observed at the Moore Medical Center, which was in the direct path of the tornado. Details of the structural design were not available at the time this report was written. Damage to the hospital is shown in Figure 9.
Damage to residential structures appears to be quite extensive, although no estimate as of yet has been given as to the number of homes damaged or destroyed. The heaviest damage appears to have occurred to the homes located between the two elementary schools damaged, as shown in Figures 10-12. But significant damage was observed throughout the path as shown in Figures 13 and 14.
Figure 10: Areas of Severe Damage to Residential Structures (Source: http://maps.google.com)

Figure 11: Extensive Damage to Residential Structures Between S. Santa Fe Ave and Penn Ln (Source: http://photos.oregonlive.com/photo-essay/2013/05/aerial_view_of_oklahoma_tornad.html)

Figure 12: Extensive Damage to Residential Structures between Hudson Ave and Santa Fe Ave (Source: http://photos.oregonlive.com/photo-essay/2013/05/aerial_view_of_oklahoma_tornad.html)
Using data available on Zillow.com, most of the homes within the damage path appear to have been built either in the mid to late 1970’s or since 2000. Figure 13 shows a foundation nearly swept clean of a home built in 2002, located near the centerline of the estimated tornado path. From the photo it can be seen that this was a wood-frame home with brick façade. Anchor bolts were used to attach the bottom plate to the foundation, but no information can be seen to indicate the quality of the roof-to-wall connections. Note that while this home was almost completely swept off the foundation, homes in the background have damage varying from minor sheathing loss to complete roof removal.

Figure 13: Extensive damage to home built in 2002 (Photo Courtesy of NWS: Norman)

Figure 14 shows the destruction of another home, this built in 1963, also located near the estimated centerline of the tornado. It is not clear from this photo alone whether anchor bolts were used or what connections were used to develop the load path from roof to foundation.

Figure 14: Extensive damage to home built in 1963 (Photo Courtesy of NWS: Norman)
CONCLUSIONS

While we recognize the need for forensic investigation and analysis of the damage to determine exact failure mechanisms, the preliminary observations presented here show that the performance of both the engineered and non-engineered structures was less than desirable. Severe damage is to be expected, but the widespread catastrophic failure of buildings should be of concern to the communities and building professionals. Efforts are needed to determine what structural systems are needed to prevent such failures. Damage is to be expected in an EF-5 tornado but the goal should be to reduce damage, particularly to structures away from the center path of the tornado. Improvements are needed to provide continuity of load path from roof to foundation, and perhaps methods that can keep walls standing when the roof fails. Ultimately, better structural systems will create a more resilient community that reduces future economic losses to Moore, OK and other cities from tornadoes.

Acknowledgements

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About the PI

David O. Prevatt is an Assistant Professor of Civil & Coastal Engineering, in the Engineering School of Sustainable Infrastructure & Environment, University of Florida, Gainesville, FL, and he can be contacted at dprev@ufl.edu.

Useful References on Tornadoes and Their Effects on Wood-Framed Buildings


