The 3 March 2020 Cookeville, Tennessee Tornado Damage Report

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ABSTRACT
This damage report focuses on the Cookeville Tornado that struck western and central Putnam County, TN in the early morning of 3 March 2020. The tornado tracked 13.2 km (8.21 miles) long and was about 457.2 m (500 yards) wide. Initially, the tornado caused minor damage, but rapidly intensified causing EF-4 damage within the city limits of Cookeville, TN. This tornado was one of ten tornadoes confirmed during the 2-3 March 2020 outbreak that were spawned by numerous supercell thunderstorms across the southeast region of the United States. This tornado is of particular interest to WERL because it was a fast-moving tornado that tracked through both forested areas and relatively populated areas. Heavily forested areas allow WERL to estimate the tornado wind speeds using tree fall patterns. Densely populated areas are of interest to us and the wider engineering community to examine the performance of structures.

Keywords: Tornado, Damage Survey, Structural Engineering, Wind Damage

1. INTRODUCTION

Cookeville, located in 127 km (79 miles) east of Nashville in the Upper Cumberland Region of Middle Tennessee, was struck by a tornado slightly before 2:00 AM CST on Tuesday, 3 March 2020. The tornado was the “7th” tornado of a series of tornadoes spawned from a single parent storm. Of all the tornadoes that occurred that morning, the Cookeville Tornado caused the most fatalities and the highest wind speeds and was rated an EF-4 by the National Weather Service (NWS). The tornado outbreak of 2-3 March 2020 produced a total of ten confirmed tornadoes which approximately occurred between 10:30 PM and 2:30 AM CST.

2. STORM FORECASTS

The NWS predicted severe weather across the Mid-South portions of the United States, which could include strong winds, large hail, tornadoes, and flash flooding. At 3 PM, a Day 1 outlook was issued that showed 5% and 2% probability of tornadoes for portions of Illinois, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, and Missouri.

3. SUMMARY OF DAMAGE

Based on a NWS Nashville survey the tornado was rated EF-4 on the Enhanced Fujita Scale (McDonald et al. 2006) that tracked across Putnam County, TN starting in Baxter and into Cookeville. Maximum 3-s wind gusts were estimated at up to 78.2 m/s (175 mph). The tornado lasted approximately 8 minutes and had a path length of 13.2 km (8.21 miles) and a path width of 457.2 m (500 yards). The estimated storm motion was East at 28.2 m/s (63 mph) (estimated by NWS). The tornado initially produced EF-0 damage, then intensified rapidly and produced EF-1 and EF-2 damage in Prosperity Pointe Subdivision. The tornado further intensified where it finally reached EF-4 intensity, destroying multiple houses on Charlton Square and McBroom Chapel Rd

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and causing multiple fatalities. The tornado continued at EF-4 intensity on Hensley drive and eastward to Echo Valley Drive, destroying more structures. The tornado caused EF-2 and EF-3 damage along Broad Street and Herald Ct. The tornado came to an end just west of Cookeville Regional Medical Center.

4 STRUCTURAL LOAD PATH

A tornado has a unique loading on structures compared to other storm types. Tornadoes typically tend to be relatively small and have steep wind gradients from the core. Therefore, it is not uncommon to see structures that are close in proximity for one to be destroyed and the other seemingly undamaged. Structures further from the core of the tornado can experience straight-line winds, whereas structures closer to the radius of maximum winds will be loaded with radial winds. Structures in or near the core of the tornado will have a large vertical load from the updraft of the tornado. The loading is therefore highly dependent on the distance and orientation from the tornado center. Regardless of specific loading type on the structure, a properly engineered structure will provide a continuous load path to ground and resist the wind loading.

4.1. Roof to Wall Connection and Roof Sheathing

The damage progression of a house usually begins with the loss of roof cover then is followed by roof sheathing loss. Roof sheathing acts as diaphragm that provides lateral resistance for the house and transfers the load to the walls (Figure 1a). Thus, it is important to properly secure roof sheathing against vertical uplift forces to retain the lateral resistances provided by the panels. If the roof sheathing is properly secured to the roof structure, the sheathing will remain attached, and the loads will transfer through the truss and to the walls. This is where the roof to wall connections is critical, if roof to wall connections fail, the roof structure can be lifted off the walls and thrown, which could lead to wall collapse (Figure 1b). Figure 1c is another example of weak roof to wall and sill plate to foundation connections. Figure 1d shows another example of roof failure due to poor connections between the column and the porch beams.

4.2 Stud to Sill/Bottom Plate Connection

It is very common to see sill plates securely connected to the foundation with anchor bolts. Many times, after a tornado, when houses are destroyed and removed from the foundation, the sill plates anchored to the foundation are the only remaining component of the house (Figure 1e). Typically, when a wood-framed wall is constructed, the bottom plate of the wall is attached to the stud using face nail connection through the bottom plate and is embedded into the end grain of the stud. For constructability, this connection securely holds the wall together standing and bracing of the walls. The wood sheathing on walls serves to provide lateral in-plane shear resistance to the wall, (i.e., shear wall). Figure 1e illustrates that the inadequacy of only using face nails to studs through sill plate and exterior wood sheathing to resist uplift from a tornado.

4.3 Sill Plate to Floor Joist Connection

It was very common for houses built in Cookeville to have a stem wall CMU foundation. A sill plate was anchored either using a flat metal strap or an j-anchor bolt to the top of the CMU. Built on top of the sill plate is the floor joist system. Figure 1f shows a typical floor joist to sill plate connection found in Cookeville. Experimental research has found that toe-nails alone are inadequate in providing a continuous secure load path under extreme loading (Morrison and Kopp

2011). For the structure in Figure 1f, the wall section above this portion of the floor joists was completely failed, thus the load path was broken before the loads reached the toe-nail connections.

4.4 Foundation/Stem wall

Inadequate installation of foundation straps was found in various houses (Figure 1g). The foundation strap shown in Figure 1g was inserted into a partially filled cell of a concrete masonry unit (CMU). Foundation straps can provide a method of a continuous load path from a rim joist to the concrete footer, but they are not meant to hold CMU together.

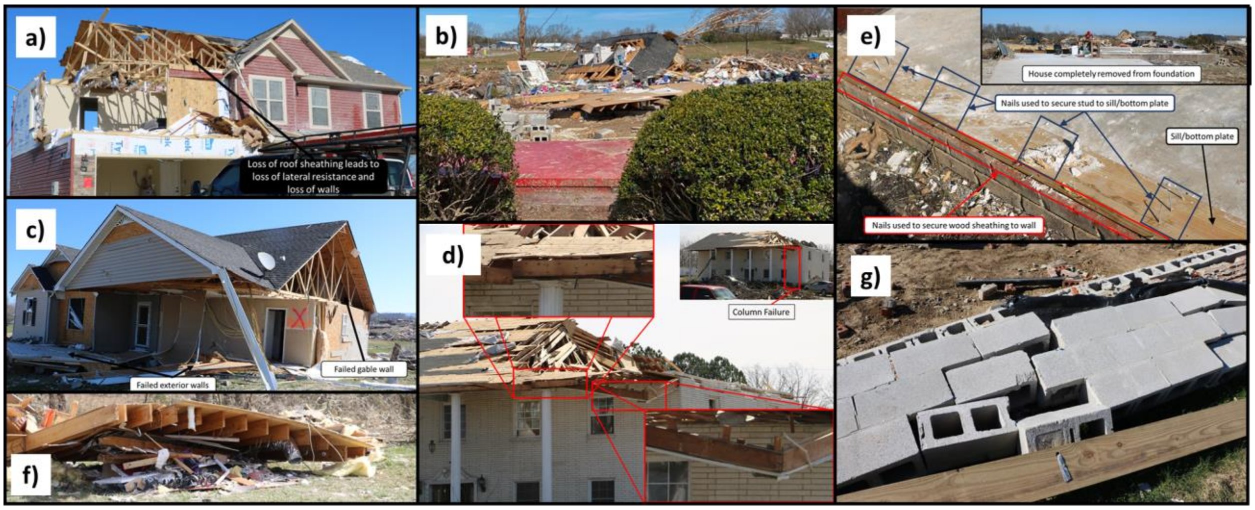

Figure 1. Observed damaged from Cookeville Tornado. a) roof sheathing loss, b) wall collapse, c) wall failure, d) porch beam failure, e) wall detachment from bottom plate, f) floor system detachment, g) stem wall collapse.

5. DISCUSSION/CONCLUSION

Load paths are well understood by engineers, but every year we continue to observe similar damage done by tornadoes. Most of the structures observed were built before the implementation of modern building codes, but some were not. The common theme with all these structures is the break down of the load path in the structures and not component failure. Most of the damage observed in the Cookeville could have been mitigated with the addition of metal straps to tie together the different structural systems. This area of Tennessee would greatly benefit from new building code adoption and stricter building code enforcement.

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