



Posted on Sat, Jun. 25, 2011

Experts challenge Home Depot building design, codes after Joplin tornado

By MIKE McGRAW
The Kansas City Star

JOPLIN, Mo. | As the monster tornado bore down on them, Rusty Howard and his two small children sought refuge in a Home Depot store.

But instead the young father, the children and four other people died when the roof came off and the walls came down, crushing them beneath a 100,000-pound concrete panel.

Within seconds the entire structure collapsed in a heap of concrete slabs, metal trusses and roofing. At least 28 other people survived, huddled in an un-reinforced training room in the back of the building.

Rescue workers found Howard with an arm wrapped around each child.

There aren't many safe havens in such ferocious, 200-mph winds. Most building codes in "tornado alley" require that commercial structures withstand only 90-mph winds, slower than many major league pitchers' fastballs.

But while all big-box stores are vulnerable to high winds, the Joplin Home Depot — even though it met local building codes — was especially at risk, according to engineers who study the destruction that tornadoes leave behind.

The Joplin Home Depot and many of the company's other stores used a popular construction method called "tilt-up wall" that The Kansas City Star found can be deadly under certain conditions.

It's a design used in thousands of warehouses, stores and schools across the country that some engineers believe has weak links that often fail — even in winds much less ferocious than those that hit Joplin on May 22.

Indeed, some engineers interviewed by The Star said building codes for big-box stores need to be strengthened, or the stores should have internal storm shelters when they're built.

"Unfortunately, the code has become the lowest common denominator," said Tim Reinhold, chief engineer at the Insurance Institute for Business & Home Safety, which does research for the insurance industry. "Engineers know they are competing for the minimum building code, and so they design right to them."

In tilt-up wall buildings, the structures are erected with concrete walls that are poured on site and lifted into place with cranes. The walls are held upright by critical connections to a relatively lightweight roof system.

Under high winds, the roof can become compromised, and the panels in tilt-up wall buildings can fall like dominoes, said Larry Tanner, a tornado expert and part of a team of engineers who traveled to Joplin to study the Home Depot collapse and other building failures for the Federal Emergency Management Agency.

"Once you lose one (wall) panel, then the dominoes all start to fall, so the failure becomes increasingly more catastrophic," Tanner said. "I was aghast at how extensive Home Depot's failure was."

If the building code had required the Home Depot store to have stronger roof-to-wall connections, it might have sustained less damage, even in such heavy winds, said Tanner and other engineers interviewed by The Star.

“It’s an efficient and low-cost building system, but it’s only stable when all the connections are working,” said Perry Adebar, an engineer who studies tilt-up wall designs at the University of British Columbia. “It’s a bit of a house of cards.”

Noting that they had never before lost a store to high winds, Home Depot officials defended the tilt-up wall design, which they’ve used in hundreds of their nearly 2,000 stores across the country, including several in the Kansas City area.

They said their engineers “fundamentally disagree” with Tanner and his colleagues.

“The structural engineer that designed the buildings designed them to code, and the connections are determined by wind load and the local requirements,” said David Oshinski, director of construction for Home Depot. “You have to remember this was an F-5 tornado. There isn’t anything you can build to withstand an F-5 tornado.”

Home Depot officials told The Star they were so confident in the tilt-up wall design that they would use it again when they rebuild in Joplin.

A few days later they said they’d use a different design: smaller precast walls made elsewhere and trucked to the site. The new design is similar to tilt-up construction but will allow quicker completion and still meet local building codes.

But many local codes are not good enough, said Tim Marshall, a meteorologist and engineer with Haag Engineering in Irving, Texas.

“This year I have seen so much carnage, and so many people who died who did not need to die. These strong tornadoes are no match for those kinds of safety rules,” Marshall said.

The new Home Depot will exceed Joplin codes in at least one respect: Company officials told The Star that the new store will have an added feature that some engineers have long recommended in such buildings.

They said it will be the only Home Depot in the nation with a storm shelter.

The final minutes

As the storm approached and sirens sounded across the city, employees at stores near 20th Street and Range Line Road in Joplin began moving customers into their stores’ safe areas.

Across 20th Street from Home Depot, at least three people died when a portion of a Walmart store collapsed. But an estimated 200 others survived, largely because many of them were taken to a concrete block structure inside the store, Walmart officials said.

Home Depot employees closely followed the store’s disaster protocols, according to company officials. They listened to a weather radio, manned the doors and swept the store looking for shoppers who needed shelter. They also directed customers to the designated “safe area,” the training room in the back of the building. Unlike Walmart, it wasn’t a concrete block structure.

Employees then locked the store’s front doors. That appears to be standard procedure at large stores. Home Depot officials said it’s done to keep wind from entering the building and forcing the roof system upward, and to ensure that everyone is accounted for and safe.

The Howard family had been out to dinner that afternoon. Edie Howard left in one car while her husband and children drove off in another. Just before the tornado struck, Rusty Howard talked with Edie by cellphone in his car, according to their pastor. Rusty, 29, told her that he and the children were headed for the nearby Home Depot to take shelter.

About that time, Home Depot employee Dean Wells, 59, of Webb City, Mo., saw several people, including Rusty and his children Harli, 5, and Hayze, 19 months, trying to get in the store’s locked front doors. Wells went to let them in.

But before any of them could make it to the training room, the roof flew off, and the walls collapsed on top of Wells and the Howards, plus Randy England, 34, of Granby, Mo.; Dennis Osborn, 34, of Seneca, Mo.; and one other person. All were killed.

The Joplin death toll stands at 156, making it the United States' single most deadly tornado in 60 years. The tornado cut a three-quarter-mile wide swath through the city, destroying an estimated 8,000 homes and more than 500 businesses.

Anatomy of a collapse

Wayne Lischka, a Leawood architectural engineer hired by The Star, said the tornado first hit the south corner of the west-facing front wall of Home Depot. That put inward pressure on the front wall panels. The tornado lifted the roof off, causing the walls to pancake, largely intact.

The same forces pushed the eastern rear wall — near where the 28 survivors were huddled — toward the outside of the building, an event that probably saved many of them from worse injuries or death, according to engineers and rescue workers.

But Lischka said the collapse actually began when the oncoming tornado — much like a vacuum cleaner — created huge upward forces on the roof.

Lischka said the roof was designed to withstand uplift pressures of about 28 pounds per square foot, strong enough for 90-mph winds. But he said the 200-mph tornado exerted upward forces of up to 90 pounds per square foot.

At that point, Lischka said, the inside bar joists supporting the roof began to bend and pull away from the concrete walls. In fact, he said, the forces were so strong that three-fourths-inch-diameter metal anchors for the joist connections — which were embedded inside the concrete walls — bent and were literally pulled out of the hardened concrete.

"This type of construction would perform very well under normal loading," Lischka said. "Tornadoes are not normal."

By the time it was over, only two short wall panels were left standing, and the store's metal roof support system was sprawled in a mangled heap behind the store and across its interior.

In defending tilt-up construction, Home Depot officials said that any big-box store would sustain the same damage their store did, no matter how it was constructed.

But that doesn't appear to be the case in Joplin.

"The Home Depot was all on the ground, except for one corner," said Joplin Fire Chief Mitch Randles.

Two other big-box retailers on the same corner, both of which were built of concrete blocks rather than tilt-up walls, were not as heavily damaged, he noted.

"Academy Sports' roof is missing, but their walls are still standing, and most of what was missing at the Walmart was the roof," Randles said.

Randles added, however, that he believes Home Depot took a direct hit from the tornado. He is not sure whether the other buildings did.

Randles said authorities may never know where every victim was when the tornado hit. But he confirmed that at least seven people died inside Home Depot and at least three died inside Walmart. Academy Sports officials said there were no deaths at their store.

Walmart spokesman Lorenzo Lopez said the company used tilt-up wall designs at some stores but more often used reinforced concrete block walls, like those at the Joplin store.

Lopez said the Joplin store's safe area, where he estimated 200 people survived, was a concrete block structure containing break rooms, rest rooms and a customer service area. He said the structure is not near an outside wall.

"We are very fortunate in terms of the impact on lives that it could have had," Lopez said.

He added that, given its internal concrete block structures, it is unlikely Walmart would add a separate storm shelter when it rebuilt.

Some engineers think that concrete block structures may be safer in a collapse than tilt-up wall buildings. If masonry block walls fail, they can come apart as they are falling, some engineers noted, leaving voids beneath them where some people could survive.

But when tilt-up wall buildings fail, the walls come down in huge sections that leave little chance of survival, unless customers are inside a hardened structure.

Tilt-wall construction

Tanner, the engineer and tornado expert from Texas Tech University, has been recording tornado-related failures of tilt-up wall buildings since at least 1999. Based on what he has learned, he said there were numerous issues that should be addressed.

He said that most tilt-up wall structures have relatively lightweight roofs and questionable lateral support systems for the side walls. Tanner also said better tilt-up structures have strong panel-to-panel connections.

Tanner also said that tilt-up wall panels were usually not connected to one another, meaning they tend to fail progressively.

“Walmart only had a catastrophic failure in one part of their store, but Home Depot was bad,” said Tanner, who studied the debris in Joplin as part of a mitigation assessment team sent by FEMA.

Tanner said his team’s final report probably would rate the Joplin tornado at less intensity than earlier estimates. They think it was an EF-4 (wind speeds of 168 to 199 mph), not an EF-5 (200 to 234 mph).

“What happens in these various storms, especially in Home Depot,” Tanner said, “is that the storm removes the roofing and roof insulation and light metal decking. And once you lose your (roof) decking, you lose the lateral support of your joist and beam system, and they become less supportive.”

Tanner and other engineers said that a concrete roof — which some Home Depot stores in hurricane country have — “would add weight to the roof system and could prevent roof failures.”

But Tanner noted that there is no need to condemn the entire concept of tilt-up wall construction.

“We just need to do a better job of supporting that (roof-to-wall) system,” he said.

Lischka, The Star’s engineering consultant, agreed with some of Tanner’s concerns about tilt-up wall buildings. But Lischka said he thought some of the changes Tanner would like to see in tilt-up wall structures would be “prohibitively expensive.”

Home Depot officials declined to specify the cost difference between lightweight roofs like the one used in Joplin, and heavier concrete roofs used in hurricane-prone areas such as South Florida.

In a report on the “Super Tuesday” tornadoes that struck Alabama, Arkansas, Kentucky and Tennessee in February 2008, Tanner and his colleagues found that tilt-up wall buildings failed under much lower wind speeds — 110 to 167 mph — than those that slammed into Joplin’s Home Depot.

FEMA also found several cases in which roof-to-wall connections in tilt-up buildings failed in Kansas and Oklahoma following tornadoes in the late 1990s.

“There are lots of different ways buildings can fail, but a consistent problem (with tilt-up failures) is the loss of roof connections, and we see that time and time again,” said John Snow, a meteorologist and dean of the college of atmospheric and geographic sciences at the University of Oklahoma.

Several engineers who were part of a different team sent by the American Society of Civil Engineers to assess the damage in Joplin also agreed with Tanner’s assessments on tilt-up structures.

“Generally speaking, I agree with the wind engineers 100 percent,” said Bill Coulbourne, a consulting structural engineer who specializes in buildings designed to withstand hurricanes and tornadoes. When tilt-up buildings collapse, Coulbourne said, “they come apart easier.”

But tilt-up wall structures have strong defenders.

“There is no huge smoking gun here,” said Dave Weber, an engineer with Allstate Consultants in Columbia, Mo., who was in Joplin to advise rescue workers.

Weber, who has designed several tilt-up buildings, said, “Obviously a more resilient connection would help at the wall-to-joist location.”

But he said nothing unreasonable was done in the design of the Home Depot building, and making the roof-to-wall connection stronger simply would move the weak link of the structure to some other area.

Jim Baty, technical director of the Tilt-Up Concrete Association in Mount Vernon, Iowa, said tilt-up wall construction had been around for decades, but it got much more popular when it became easier to move concrete trucks and cranes to construction sites.

He said that he was aware of Tanner's work on tilt-up structures but that he hadn't evaluated Tanner's conclusions.

"Is a tilt-up building safe in a tornado? There is a lot of evidence out there that says yes," Baty added. "But at what point do you draw the line? That is a question for the structural engineer."

Codes upgrade?

A Florida newspaper suggested after the Joplin disaster that it might be time for tornado-prone states to study the costs and benefits of standardizing and beefing up their building codes the way Florida did after Hurricane Andrew in 1992.

"As the Florida experience has shown," the Sarasota Herald-Tribune noted on May 24, "beefed-up construction standards come at a price, but they can also save money and lives."

Buildings in parts of Florida require structures to withstand 150-mph winds, while most of tornado alley has only a 90-mph standard. Codes in Missouri vary from city to city.

The insurance industry, which is paying out billions of dollars this tornado season, is backing such changes.

"We support uniform statewide building codes," said Chris Hackett, of the Property Casualty Insurers Association of America. "They promote public safety and protect insured structures."

A team of engineers from the American Society of Civil Engineers agreed. A post-tornado report from the organization said Joplin residents "cannot rely on the current building codes and construction techniques ... if they want these buildings to better resist the wind uplift and lateral forces of any future tornadoes."

The ASCE said in its interim report that building-code improvements now required in hurricane country would help in tornado-prone areas with winds of up to 135 mph, dismissing "myths" that tornado-resistant buildings couldn't be constructed.

But it doesn't appear that's going to change codes anytime soon in tornado alley. Although the issue came up recently in Oklahoma, it might go no further there than incentives for building storm shelters. And as Florida discovered, codes that are too strict could mean higher building costs that will discourage construction even further.

There's also the added complication that strengthening structures for the straight-line winds of a hurricane is much simpler than bolstering them against wildly unpredictable tornadic winds.

At a recent work session, Joplin City Council members said they might require relatively inexpensive changes to the local building code, such as "hurricane clips" (metal reinforcing to better hold a home's roof to its walls) and beefed-up concrete block foundations.

But they have indicated they will not require any major code changes, such as requiring storm shelters, arguing they did not want to institute requirements that would be costly to homeowners or drive businesses to other nearby towns.

If Missouri had a statewide building code such as the one in Florida, those concerns would diminish. But two such proposals suffered quick defeats recently in the Missouri General Assembly.

The idea has been discussed at recent meetings of the Interim Committee on Disaster Recovery, led by state Rep. Shane Schoeller, a Willard Republican. But the idea isn't likely to go any further.

"I made it very clear that we are not going to overreact in light of what happened," said Schoeller, who added that he was leaning against a statewide code. "We are going to be very prudent."

Gov. Jay Nixon said shortly after the tornado that what happened in Joplin would prompt consideration of stronger building codes and other measures designed to protect the public. But Nixon questioned whether codes could be written to prevent the horrific destruction witnessed in Joplin.

So what's left is what Tim Marshall, the meteorologist and engineer from Texas, called acceptable risk.

"It's acceptable risk in the center of the country. We are at the mercy of building codes, and that is 90-mph winds, and anything above that, all bets are off," he said.

Until codes are upgraded, Marshall and other engineers said, Home Depot and other big-box stores should build hardened storm shelters inside their facilities.

"Large span structures like that are going to fail. It's going to happen," he said. "Schools and hospitals are doing it (building shelters) more and more, so why shouldn't commercial stores do it? It's fantastic, and I commend Home Depot for doing that. It should set an example for others to follow."

To reach Mike McGraw, call 816-234-4423 or send email to mcgraw@kcstar.com.

© 2011 Kansas City Star and wire service sources. All Rights Reserved. <http://www.kansascity.com>