Earthquake Drill Finds Weaknesses in Steel High-rises

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Simulation of a massive Southern California quake suggests about 5 such buildings would collapse. But many engineers say other buildings are riskier and should receive priority in retrofit plans.
By Jia-Rui Chong

Modern steel buildings have long been considered among the most sturdy in the event of a major earthquake. But a model of a massive quake in Southern California has sparked debate among scientists and engineers over whether these structures are more vulnerable than previously thought.

The Great Southern California ShakeOut, the nation's largest quake drill, suggested that about five high-rise steel buildings in the region would collapse in the modeled magnitude 7.8 quake.

High-rise steel buildings sustained less damage than unreinforced brick buildings and older concrete buildings in the analysis. But the damage they sustained was greater than expected based on the standard building design formulas.

"It has huge implications," said Lucile Jones, a U.S. Geological Survey seismologist who served as chief scientist for the ShakeOut project. "When these types of buildings collapse, we could have 1,000 people in them. That's something to worry about."

The findings come 14 years after the Northridge earthquake, which exposed weaknesses in some older steel buildings.

Jones said she hopes that policymakers will use the results of the November drill as they develop guidelines for retrofitting existing buildings and set standards for new buildings. But not everyone finds the ShakeOut scenario so worrisome.

Luke Zamperini, principal inspector for the Los Angeles Department of Building and Safety, said the scenario is interesting but doesn't necessarily demand action.

He was not convinced that an earthquake of that size would cause any steel high-rises to collapse.

"It's hypothetical," Zamperini said. Changing building codes "is based on forensics, on what we've seen happen. Engineers are not willing to make changes on what people theorize might happen."

Standard building design formulas rely on the average effects of earthquakes recorded worldwide, said Swaminathan Krishnan, an assistant professor of civil engineering and geophysics at Caltech who led the modeling. But information on earthquakes the size of the one modeled -- a magnitude 7.8 on the San Andreas fault -- is sparse, he said.

Simulations of this size became possible only in recent years, thanks to supercomputers that also allowed scientists to feed in specific geological and topographical details for Southern California.

The model produced a lot of long, rolling ground motions in the Los Angeles Basin that are problematic for tall steel buildings, especially those built before the 1994 Northridge earthquake.

That quake exposed problems in a type of welding technique that had been popular for several decades. A Federal Emergency Management Agency study of 185 steel-frame buildings in the San Fernando Valley showed that two-thirds had damaged welds after the temblor.

About half of the damaged welds were cracked and the rest had more serious defects. Eleven percent of the buildings sustained damage to more than 10% of their connecting welds, which are critical to the buildings' structural integrity.

Krishnan estimated that across Southern California there are about 150 of the kinds of buildings that sometimes had problems in the Northridge quake.

Krishnan modeled hypothetical buildings at 784 locations and fed ground motions into the computer. Buildings fell at about 12% of the locations, but none of the collapses in his model matched up to the actual locations of tall buildings.

Because the actual buildings are close to the model's collapse zones, Krishnan recommended that emergency planners prepare for eight collapses. Standard formulas would have expected zero.

"I think this is a big difference," Krishnan said. "The building codes have not assumed for ground motions as strong as these."

A panel of structural engineers reviewing Krishnan's results told the Geological Survey they considered "one or more" collapses to be more realistic.

After debate, the ShakeOut authors compromised by estimating five collapses.

Thomas Heaton, a Caltech professor of civil engineering who was not involved in the modeling, said he was glad the ShakeOut brought attention to steel buildings.

"Our building codes have served us extremely well, but sometimes the public gets the general idea that with modern buildings, there are no problems," he said. "Well, the truth of the matter is, there's a lot of work to do."

Ronald Hamburger, a former president of the Structural Engineers Assn. of California who was part of the review committee, agreed that the collapse of a few steel high-rises in such an earthquake was likely, but he, like many structural engineers, worried about focusing too much on the steel high-rises.

"There are the hundreds of other buildings that are going to collapse," he said. "It's much easier and financially doable to fix the other buildings than figure out which five steel buildings collapse.

"Given the total inventory of buildings that exist in California today, high-rise steel-frame buildings are still among the safest buildings we have," Hamburger said.

Despite the debate, Jones said she's happy that the process has produced more consensus among scientists and engineers that an earthquake of this kind would bring down tall buildings.

"Just waiting to see what falls down and prohibiting it . . . means we have to kill people before we say, 'Build it that way,' " she said.

"As scientists, we would prefer to find a way of incorporating the knowledge we have into the process."

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