

Lessons from the Sept. 19 Mexico Earthquake



Common Collapse More than 60% of the 44 building collapses in the Sept. 19 quake involved a reinforced-concrete-column-beam system. *Photo by Pablo Heresi*



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On the 32nd anniversary of the magnitude-8.1 earthquake that devastated Mexico City on Sept. 19, 1985, 41 U.S. seismic experts were in a workshop near Los Angeles, polishing a new tool to identify “killer” buildings: non-ductile concrete structures that often perform poorly in quakes. Suddenly, the

attendees started getting pager alerts from the U.S. Geological Survey: A magnitude-7.1 quake had struck about 120 kilometers from Mexico City.

When the dust settled from the Sept. 19, 2017, Puebla-Morelos quake—the most damaging seismic event in Mexico since the 1985 quake—44 buildings had partially or fully collapsed in Mexico City (ENR 10/9 p. 14). As of Oct. 17, the known death toll was 369. Of those fatalities, 228 were in the capital, according to Mexican officials.

Of some 1,000 Mexico City buildings damaged during the Puebla-Morelos quake, 200 to 300 need major repair, such as new walls, steel braces or enlarged columns and beams, says Sergio M. Alcocer, a research professor at the National Autonomous University of Mexico and a member of the all-volunteer advisory committee on structural safety, which develops the Mexico City building code. “The numbers will become more clear in the next few weeks,” he says.

In the quake, 27 of the buildings that collapsed had reinforced-concrete columns with flat slabs. Nine were unreinforced masonry structures. Four collapses involved structures with confined masonry walls; three had reinforced-concrete frames; and one building had a mixed steel-and-concrete structure, according to a report by a team from Stanford University, which studied the damage in Mexico during a Sept. 19-25 trip.

Non-ductile concrete structures, which include flat-slab systems, were the very subject of the Sept. 19 workshop, convened by the Applied Technology Council. Participants at the meeting were reviewing trial runs of a new methodology to more easily identify, analyze and predict the quake performance of the vulnerable concrete structures. The methodology tool is the product of the 90%-complete ATC-78 project.

To help complete its new tool, ATC created a 14-person multidisciplinary team, including structural engineers, building instrumentation researchers, and geotechnical and seismology specialists from around the world, to study the Mexico City buildings. From Oct. 9-13, the team, which included two members from Mexico, collected detailed information on structural design, vibration properties, site and seismological characteristics, strong ground-motion records, and performance of engineered reinforced-concrete structures.

The data will be helpful for the ATC-78 project, funded by the Federal Emergency Management Agency. It also will be helpful for the ATC-134 project, funded by the National Institute of Standards and Technology. ATC-134, just getting underway, will investigate and correlate all the different earthquake codes around the world so that all engineers are on the same page, says Ramon Gilsanz, a partner of structural engineer

Gilsanz Murray Steficek and the ATC team leader in Mexico.

Jon A. Heintz, ATC's executive director, is more than satisfied with the team's findings. "We received comprehensive information on a building's behavior that was never available before," he says. "We really think this work will contribute to the state of knowledge, both domestically and internationally," to help avoid negative effects in future events, he adds.

Similar to the 1985 quake, many of the collapsed buildings—all but a handful built before seismic codes were strengthened after the 1985 quake—had reinforced-concrete structures with weak lateral-load-resisting systems.

More than half of the collapsed buildings—none greater than 10 floors—had a soft story, or a raised first floor, typically for at-grade parking directly under the building. "My position is that soft stories should be outlawed," says Alcocer. Corner buildings are also tricky, he says.

The most common cause of the failures was insufficient or badly anchored transverse steel reinforcement, called stirrups, says Eduardo Miranda, the Stanford engineering professor who led the Mexico trip.

Stirrups could be too far apart or bent only 90° at the corners, as opposed to 135° inward to the center of the column, as is required in modern seismic codes, explains Miranda. Other commonly observed failures were in the slab-column connections and beam-to-column connections, he adds.

The Stanford report recommends a government mandate to evaluate and, if necessary, seismically upgrade existing vulnerable buildings. "They may be in danger of collapse in future earthquakes," says the report.

The flat-slab method of construction is a beamless floor system in which a reinforced-concrete slab with uniform thickness is directly supported by columns, says Miranda.

In the U.S., flat-slab systems are allowed only to resist gravity loads.

A solid flat-slab system, also known as a "flat plate" system, is not commonly used in Mexico because it is not economical for longer spans. It becomes too heavy and inefficient, says Miranda.

To make the slab lighter and save material, voids are created in the concrete, which leaves thin ribs in both directions and creates a two-way joist system. Slabs typically range in thickness from 10 in. to 16 in.

There are several ways in which the voids are created for the two-way-joist flat slabs, says Miranda. One system uses fiberglass forms, which are removed after the concrete has hardened; the other system employs blocks of polystyrene, which are left in place. In some cases, hollow concrete masonry blocks are used, which also are left in place.

During its tour, the Stanford team also studied ground motions that had been recorded in accelerograph stations in Mexico City. "We have found that, except for the ground motion in one recording station, the level of forces generated by the earthquake did not exceed the site-specific design spectra computed using procedures" in the Mexico City building code, published in 2004, notes Miranda.

Mexico City expects to issue an update of the 2004 code, likely to be adjusted because of the quake, in November. “The code was 95% ready on Sept. 18,” says Alcocer. “The original idea was to announce it on Sept. 19.”

Further, the advisory committee is working on developing seismic retrofit rules for soft-story buildings, corner buildings, non-ductile-concrete and masonry buildings. Owners would have to evaluate their structures and carry out seismic retrofits if there is a collapse hazard.

Retrofit rules will take time to develop. Implementation could take many years. “We have to sort it out,” says Alcocer.

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