Thin walls with potentially fatal consequences

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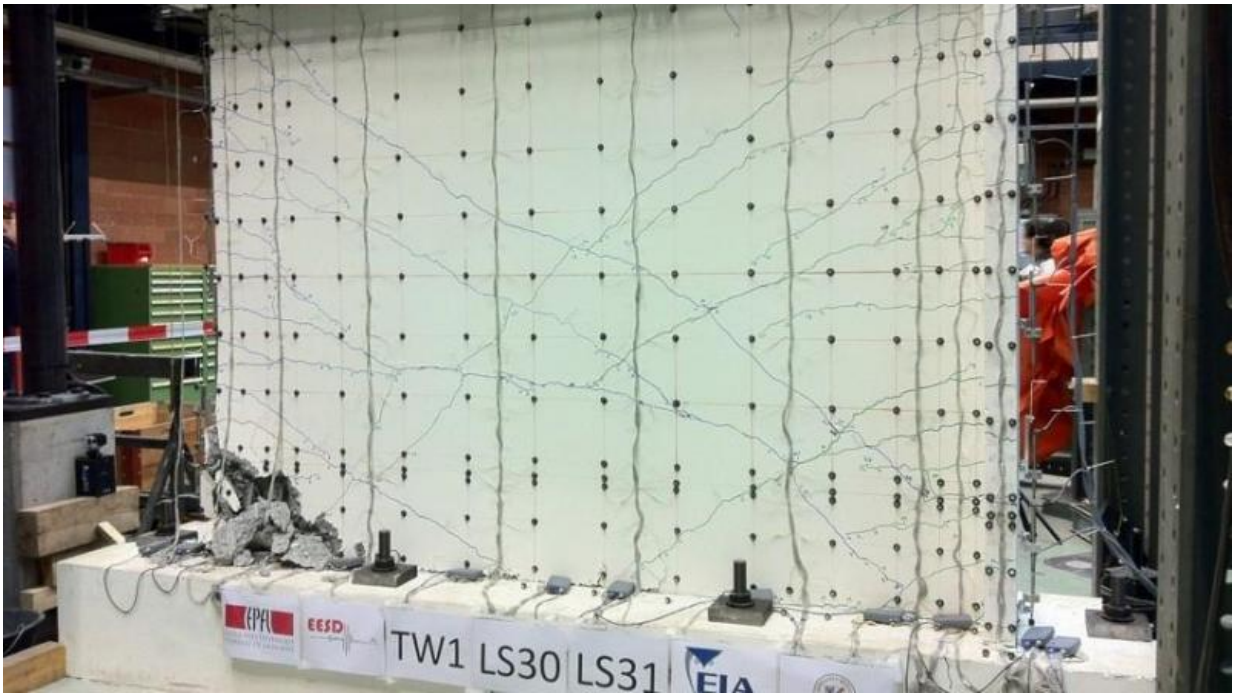
Given the choice between safer and cheaper construction, many housing design companies in earthquake-prone developing countries see themselves forced to save on expensive construction materials and opt for the latter. EPFL structural engineers have gathered new data on how these structures respond to earthquakes, and in which circumstances they may fail.

Earthquakes almost never kill people by themselves. Instead, the high toll they take can be explained by a lack of resilient buildings and infrastructure. In Chile in 2010, many thin-walled reinforced concrete buildings were damaged in one of the strongest earthquakes ever recorded. Yet today, more and more structures with even thinner walls are being built in some Latin American countries. Recently, engineers from EPFL evaluated the stability of thin reinforced concrete walls to understand how they fail. Their findings are published in the journal *Bulletin of Earthquake Engineering*.

To find out how very thin-walled structures behave in an earthquake, João Almeida and Angelica Rosso, two of the study's authors, tested two 80-millimeter-thick, 2-by-2.7-meter wall segments, similar to those used in low-income housing projects in some South American countries. By clamping the wall segments to the floor of the laboratory and loading them with five actuators strong enough to slowly bend the walls back and forth in different directions, they simulated the impact of an earthquake on the structure. By slowing down the process the researchers had time to watch the damage spread and to find out how cracks propagate across the wall, ultimately destabilizing it.

"The data we gathered in our experiment is unique," says Katrin Beyer, the principal investigator of the study. "It is the first to contain detailed measurements of a so-called out-of-plane wall failure, which means that the wall structure was irreversibly deformed perpendicularly to its surface." According to Beyer, it was also the first time that displacements greater than the wall thickness itself had been observed under these conditions. By the end of the test, the wall's reinforcement bars had bent, with the concrete crumbling in one corner of the structure. Thanks to an array of sensors, cameras, and strain gauges, the researchers were able to capture and analyze every motion leading up to the collapse of the wall.



Credit: EPFL – EESD

To withstand an earthquake, a building's structure has to be ductile enough to ride out the vibrations caused by the earthquake's seismic waves. But because seismic design is typically more expensive and requires more expertise, poorer parts of developing and emerging countries are often built with sub-standard buildings. A case in point: closer investigation of the housing units that collapsed in the 2010 Chile earthquake revealed that their reinforced concrete walls often did not meet the recommendations of the country's construction code.

A dangerous loophole

The reason they were built at all, explains Beyer, can be found in a loophole in the construction code. All it takes is for an engineer to deem

thin walls sufficiently robust, and the project can go forward. "The real solution would be to more strictly enforce and further tighten the building code in countries that are prone to earthquakes," says Beyer. But until then, she says, the loophole will subsist.

Credit: EPFL – EESD

Rather than focusing on Chile, the scientists focused on neighboring Colombia, a country with a lower, nonetheless dangerous, seismic risk. In Colombia, demand is high for low-income housing in medium to high-rise buildings built using reinforced concrete walls. But even though housing design engineers in Colombia are aware of the risks earthquakes bring, building permits do not always reflect this. And with concrete and reinforcement bars often making up the lion's share of a building's cost, constructors often opt to use even thinner walls – sometimes only half the thickness of those used in Chile.

A duty to share

"Because we are lucky enough to have access to such expensive research infrastructure, we see it as our duty to make our data available to the scientific community, so that researchers and engineers around the world can exploit the results," explains Beyer. Together with the Colombian partners at the Universidad del Valle in Cali, the School of Engineering of Antioquia and the University of Medellin in Colombia, they recently received a second round of funding to further improve the understanding of the structural behavior of these structures and to study cost-effective approaches capable of stabilizing existing thin-walled reinforced concrete structures.

More information: Angelica Rosso et al. Stability of thin reinforced concrete walls under cyclic loads: state-of-the-art and new experimental findings, *Bulletin of Earthquake Engineering* (2015). DOI: 10.1007/s10518-015-9827-x

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