

# Retrofitting old buildings to make them earthquake safe

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Researchers hope to give building owners a number of different options at a variety of price points to retrofit their buildings and make them safer. Some of these options, like the shape-memory alloy brace, have never been tested before. Others have been tested, but not at this scale or capacity.

Non-ductile reinforced concrete buildings are among the most common structures in the United States. They are also among the most deadly.

Structures built prior to the 1950s in California and prior to the 1980s in the central and southeastern United States were typically not designed with proper details to perform adequately during earthquakes.

Through a grant provided by the National Science Foundation, researchers at the Georgia Institute of Technology—along with partners at Virginia Tech, Rice University, Howard University and the University of California, Los Angeles—are testing retrofits that potentially can make these buildings safer and more secure.

"These buildings are considered among the most deadly in the United States," said Reginald DesRoches, Karen and John Huff Chair and professor in Georgia Tech's School of Civil and Environmental Engineering. "Their reputation comes from the fact that there are so many of them and they are brittle, which means they will not have a lot of bend before they fail and collapse."

Georgia Tech and its partners are studying how a full-scale [reinforced concrete](#) building reacts during large-scale testing. This testing shakes the [structure](#), allowing researchers to assess different kinds of techniques to make similar buildings more durable so they don't collapse during an earthquake.

"Our focus right now is trying to understand from a scientific perspective what works and what doesn't," DesRoches said. "We built this unique structure, which is split into different bays, that allows us to test three different retrofits as well as one bay without any added support."

## **The building**

According to DesRoches, it is unusual for researchers to build such a massive structure allowing this type of testing.

Originally, the research team tried to locate an existing building they could test, but they then realized there were benefits to building a new structure.

"It is a full-scale building that was constructed from plans of a building that was built in the 1950s in California," DesRoches said. "We know exactly what is in the columns and how it was designed."

## **How the structure is tested**

The building was constructed so that it was sliced up into bays, allowing researchers to actually test different portions of the building separately and evaluate different retrofit measures.

Four different bays, or different test structures, were tested.

Researchers mounted a shaker on top of each research bay, clamping it down to the building. This shaker produced more than 100,000 pounds of force, and researchers could control the sort of harmonic load or non-harmonic load needed.

"Nobody has really tested anything at this scale the way we are testing it with a large-scale shaker on top of the building," DesRoches said. "From a technical perspective, this is very unique."

With this equipment, researchers replicated the 1940 El Centro earthquake and the 1994 Northridge earthquake. By monitoring hundreds of instruments attached to the structure, researchers were able to get a detailed understanding of what exactly took place at different

points in the building and essentially get a picture of the entire structure at any point during testing.

## The retrofits

The research involved testing three retrofits to strengthen the building's columns after an initial series of tests on the virgin structure or bare columns.

The first retrofit is a black carbon-fiber wrap. The idea is when you wrap the columns with something very strong, you actually confine them.



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"One of the biggest problems with these non-ductile columns is that they are not well confined," said DesRoches. Confinement takes place by placing steel horizontally along the length of the column. This is typically referred to as transverse reinforcement.

In older reinforced concrete buildings, the transverse reinforced is spaced too far apart – typically around 12-16 inches apart. In new building, the code limits the spacing to 4 inches in critical sections of the column.

In the old buildings, there are not enough non-ductile columns and they are spaced too far apart—typically about 16 inches apart. In new buildings, by contrast, they are spaced just 3 to 4 inches apart. The wrapping confines the columns, making them stronger and more ductile. That means the structure can tolerate more movement.

The second retrofit is similar to first. It is a round carbon-fiber tube that has been filled with concrete. The concrete is grouted in so it is confining or squeezing the column. According to DesRoches, when you squeeze the column in such a way, you increase the ductility and the strength of the column.

The third and final retrofit uses a "smart" material known as a shape-memory alloy. It can deform significantly and then revert to its original shape.



"You can bend it, and it does not break," DesRoches said. "The idea behind seismic retrofit is that you want the structure to bend, but not break. So we have these braces and shape-memory alloy cables in this brace, and when it deforms, it puts the force right back on the structure to pull it back into position."

DesRoches continues, "What we're trying to do in an earthquake is limit the deformation, particularly in an area where we know it is vulnerable. In this case, it is the base of the structure. We want to limit it to a level that we know is safe, and we believe this material can do that for us."



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## **What researchers hope to find out**

Researchers hope to give building owners a number of different options at a variety of price points to retrofit their buildings and make them safer. Some of these options, like the shape-memory alloy brace, have never been tested before. Others have been tested, but not at this scale or capacity.

## **How the tests performed**

During the test, researchers want to see various amounts shaking. When testing the retrofits, researchers start with low levels of shaking and gradually build up to larger levels of shaking.

"You may not see as much shaking as when we tested the virgin structure because in that case we went to the point where we had to stop because the structure was about to collapse," DesRoches said during the final test. "You do not see that amount of shaking because we're testing a retrofit that has been very successful and effective in limiting the deformation that you get in the structure."

Overall, DesRoches and his team were pleased with the testing.

"I feel great about what I saw," he said. "I was here for the first test, and the structure was classicly dangerous—what we call soft story—where the first story moved so much that if we hadn't had the safety ropes inside, it would likely have collapsed."



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He continued, "You can see in the last test, it moved very little and it performed well. In fact, we almost made it too strong in a sense. I wouldn't mind seeing a little more movement. We could have made it half as strong with half as much material and still received good performance from it. We did not come anywhere close to pushing those devices on the last test. It performed very well."

Now researchers will spend the next three to six months combing through and analyzing all the data they've gathered during six months of testing.

## **Future of structure**





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Meanwhile, researchers are looking at a number of ways to continue utilizing the structure.

The first bay that they tested without any retrofit is significantly damaged, so they are looking at ways to repair it.

"This is the type of problem that we know we have after earthquakes," DesRoches said. "We have a structure damaged, and they typically tear down the building if they feel it is not safe to reoccupy. However, we

think there may be opportunities to develop rehabilitation methods to actually preserve and reoccupy the [building](#) without completely demolishing it."

Provided by Georgia Institute of Technology

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