Building A Better Earthquake Defense

Pontificia Universidad Catolica de Chile

Juan Carlos de la Llera is no stranger to the sight of toppled bookshelves, broken windows and crumbled buildings. At five years old, he experienced his first earthquake — the first of many. De la Llera lives in Chile, a country that's endured more than a dozen earthquakes of 7.0 or higher on the Richter scale during the past 20 years. "My whole life was surrounded by earthquakes," says De la Llera, Ph.D. "But from all my memories of these events, they were nothing like the one in 2010."

On Feb. 27 that year, De la Llera and his family awoke in the middle of the night — along with millions of other Chileans — as the ground shook beneath them for two minutes. To De la Llera, it felt different from other quakes. His instincts were correct. An 8.8-magnitude quake, it was the fifth-strongest earthquake recorded since 1900.

The quake destroyed many lives and structures, but amid the rubble there was some encouraging news. Of the buildings that survived the quake, several included antiseismic technology designed by Pontificia Universidad Católica and implemented by SIRVE, the Santiago-based seismic engineering firm that De la Llera cofounded. It was the

culmination of many years of research for De la Llera — he had helped develop antiseismic technology while at Pontificia Universidad Católica de Chile. The 2010 earthquake ended up being a proving ground for SIRVE's seismic protection devices. It showed the world what De la Llera already knew: There was a way to improve current building designs to protect structures — and just as important, the structures' contents.

The Cost of Quakes

> *Chile is only one of many nations that must contend with serious earthquakes. A study from the Center for Research on Epidemiology of Disasters points to the worldwide significance of earthquakes: From 2000 to 2009, nearly 60 percent of the people killed by natural disasters died because of earthquakes.*

Death tolls from earthquakes have risen during the past two decades. During the 1990s, the yearly average was 43,000. From 2000 to 2009, it increased to 78,000. Some experts suggest that's due, in part, to a population shift toward urban centers.

These natural disasters carry a hefty price tag. The earthquakes that occurred from 2000 to 2009 led to economic damages of about $960 billion. And there's plenty of heightened concern about the effects of future quakes, considering eight of the 10 most populous cities in the world are sitting on fault lines.

A Response to Seismic Waves

In Chile, residents know there will be more large earthquakes. But no one has the answer to a looming question: When? "For that, we need to prepare our lives, our construction. We have to be alert, always," says Álvaro Ossa, deputy director of technology transfer and intellectual property at Pontificia Universidad Católica de Chile. "We need to stay in continuous preparation."

For more than 15 years, De la Llera had been preparing — starting with his basic research in mechanics and structural engineering. He didn't realize it at the time, but ultimately De la Llera would help design some of Chile's most important structures to survive the 2010 earthquake.

After receiving a doctorate in civil engineering at University of California, Berkeley, De la Llera returned to Chile and presented a project to the Chilean government, requesting funding for developing seismic protection technology. "The government said, the only outcome we ask is to create a company, to transfer the technology to society," says De la Llera.

He helped develop seismic protection technology along with Carl Lüders, Dpl. Ing.; Thomas Fischer, M.Sc.; Mario Álvarez, M.Sc.; Henry Sady, Michael Rendel, M.Sc., André Coté, Ph.D.; and Ignacio Vial, M.Sc. (now general manager at SIRVE).

One approach they used was energy dissipation. That entailed placing U-shaped devices (about 20 centimeters long and made of annealed steel), in X-shaped bracings in between the floors of a building, to reduce the deformations and forces that are transferred to a building during a quake. The idea is to concentrate the damage in the devices, which absorb the earthquake's energy in the form of heat. After a quake, the devices can be replaced if necessary — like changing shock absorbers in a car. SIRVE now has a patent for that design.

Energy dissipation provides a useful way to protect buildings, but De la Llera notes it's not nearly as radical as another technique, called seismic isolation. "You can reduce up to 90 percent the level of movement," says Vial, SIRVE's general manager. "The thing that will be moving is the ground and not your building."

De la Llera has a poetic description: “Isolation is basically like hanging the structure from heaven, and trying to make that independent from the ground,” he says. “Physically you’re not doing that, but that’s the response of the structure.” De la Llera saw opportunities to improve upon existing seismic isolators. Together with a VULCO, a Chilean manufacturer, he and his team at Pontificia Universidad Católica de Chile spent several years designing new elastomeric compounds — materials made of natural rubber. They created a system that places sliders (constructed of layers of the elastomeric compounds and steel) between two metal plates at the base of a structure — allowing the earth to shake while the building on top slowly moves as a rigid body.

These new technologies represent a departure from the traditional approach to seismic design in Chile. Historically, the focus was to create buildings that were strong enough to resist the earthquake’s vibrations, caused by seismic waves. But that approach can fail to protect the building’s contents. “If you design a building that is like a stone, you will not have problems in the structure itself,” says Vial. “But everything inside the building will shake strongly, and you will have a lot of damage.”

That was evident in the 2010 earthquake’s aftermath. For instance, Chile’s wine industry suffered nearly $1 billion in lost revenue, as the quake’s forces cracked open barrels and storage vats. Santiago’s main airport wasn’t fully operational for several weeks, due in part to nonstructural damage in ceilings, mechanical equipment, access bridges and air-conditioning systems.

Says Vial: “That is something that’s changed a lot — the idea that we have to focus not only on the structure, but the contents that are inside.”

In 2001, De la Llera began efforts to cofound SIRVE, a structural engineering firm that specializes in seismic protection systems. The company officially launched in 2003.

De la Llera notes that Pontificia Universidad Católica de Chile is very involved in technology transfer today, but the situation was different when he cofounded SIRVE. “When we did this, the university did not have experience commercializing technologies,” he says. “This was probably like many other universities in Chile.”

The university formalized its technology transfer to SIRVE in 2012, when it issued a licensing agreement. The technology transfer office was formed after SIRVE was initially founded, says Ossa — but he notes that Pontificia Universidad Católica de Chile has supported the company’s research for years. “The university has helped get nearly $1.5 million in public funding in the last 10 years,” he says. That includes funding from Chilean public agencies like CONICYT and CORFO. Pontificia Universidad Católica de Chile also has a 32.5 percent investment in SIRVE, says Ossa.

A Dramatic Proving Ground

De la Llera and his SIRVE colleagues were convinced they had a better way to protect structures from earthquakes. The real challenge was persuading building owners to try their solutions. In the early days, De la Llera heard an all-too familiar response. “They told me, ‘I think it’s great, but why should I be the first to try it?’”

Gradually, some clients agreed to be one of the first. By 2010, 13 structures in Chile were built with SIRVE’s and VULCO’s antiseismic technology.In 2009, SIRVE completed one of its highest profile projects, literally and figuratively. The 54-story Titanium Tower, Santiago’s tallest building at that time, used SIRVE’s technology. But most construction and engineering firms remained skeptical of SIRVE’s antiseismic protection systems. “They would say, ‘Those are beautiful things for the future, but not for now,’” says De la Llera.

That changed after Chile’s massive 2010 quake. More than 500 people were killed, and estimates of the economic cost

reached as high as $30 billion (about 10 percent of Chile's GDP).It was a natural disaster that no one wanted, but it was also a showcase for the effectiveness of SIRVE's technology.De la Llera had conducted countless seismic tests in the lab, but this was the test that really mattered.

Santiago's tallest Titanium Tower stood without damage through this massive earthquake. Other testaments to SIRVE's innovative technology were the Coronel port in southern Chile, which SIRVE helped design by placing seismic isolators in between the deck and the piles.

The epicenter was very close to that port — and it was the only port in the region that didn't sustain damage from the quake. Santiago's Titanium Tower was not damaged either. Another stark example was found at the new Military Hospital in Santiago that used SIRVE's technology and VULCO's seismic isolators at the basement of the structure. The project included isolators for the main building with the operating rooms and the storage room for valuable equipment — but not for the adjacent building with the patient rooms. The quake caused nonstructural damage to parts of the building with patient rooms, but not in the main building that used SIRVE's technology. "The difference was significant," says De la Llera.

Preparing for Future Quakes

The 2010 Chilean quake was a compelling demonstration of seismic isolation's effectiveness. That means De la Llera doesn't have to convince people to try it — but it's also brought a lot of new seismic engineering competitors to Chile. Although that's a challenge for SIRVE, De la Llera says his company operates in a notably different way from other engineering firms.

"This company is actually a bridge between the university and the industry," he says. "It's basically continually developing new things. I keep working with students and researchers, Ph.Ds and post-docs, developing new technology." He says most companies don't focus on innovating — they stick with a few basic designs. "They're not necessarily looking for the optimal solution for an owner," he says. With Santiago's Titanium skyscraper, instead of using energy dissipation devices for every floor, SIRVE developed a new device that would connect every three floors, which increased efficiency nine times.

In some cases, SIRVE's technology can be added to existing buildings. The company is working on retrofitting a cathedral in Chile that's more than 200 years old. SIRVE also helped design a seismic protection solution for a telescope that's being constructed in Chile. It's a€1 billion ($1.31 billion) project slated for completion in 2022 and will house a mirror 40 meters in diameter – that's four times the width of the best optical telescopes currently in use.

But this technology isn't just intended for big-budget projects. "Producing very low-cost seismic protection systems is a main goal in my life," says De la Llera. "We're trying to lower the prices as much as we can so this technology goes all over." That means other parts of the world — SIRVE is doing structural engineering consulting in New Zealand, Peru, Argentina, Bolivia and El Salvador and is in discussions for some projects in Colombia.

But primarily, it means protecting as many people as possible. "We are very focused on introducing these technologies to low-cost buildings, to low-income housing — people who suffer a lot in quakes," says Vial. "We want to show there are low-cost products to use for high social impact in society."

When structural damage is minimized, that will liberate funds that governments currently must devote to reconstruction costs. Says De la Llera: "If you can free up those resources from the Chilean budget, obviously you're going to be making this country richer, and you're going to use those resources in a much better way."

In Spanish, “sirve” refers to something that is useful. It’s also a driving force for De la Llera and the company’s 50 employees. “If we can save people’s lives, if we can save investment in industry, we have accomplished our goal,” he says.

To see available technologies from research institutions, click here to visit the AUTM Innovation Marketplace.