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By Kevin Wilcox

Workers remove the roof from a school in Peru, the first step in a student-led retrofit designed to help local schools withstand strong earthquakes. Photo by David Hermoza

A seismic retrofit of a school in the mountains of Peru highlights an inexpensive solution to a common problem in the earthquake-prone country.

November 1, 2011--High in the mountains of Peru, 7,000 ft above sea level and a six-hour drive along dangerous mountain switchbacks from the capital of Lima, residents of the tiny community of Chocos are celebrating the completion of an unlikely engineering project that provided their children with a safer school and could serve as a national model for cost-effective seismic retrofitting of adobe structures.

This summer, GeoHazards International (GHI), a nonprofit organization in Palo Alto, California, assembled a team of engineering experts and students, made the trek to Chocos, and conducted a complex retrofit of the adobe school there as part of a larger effort to educate the residents about mitigating their risk from Peru’s frequent strong earthquakes. Since 1970, 15 earthquakes rating 6.0 or stronger on the open-ended Richter scale have struck Peru, killing more than 102,000.

Windows removed and cracked blocks replaced, the school is ready for the geomesh. Courtesy of GHI/Stanford/PUCP

"They knew they were at risk," says Brian E. Tucker, the president of GHI. "Their buildings were cracked because of the 2007 Pisco earthquake." Some areas of Peru are still struggling to recover from that quake, an 8.0 on the Richter scale, which killed 519. "They really knew their schools and their homes were very vulnerable, but they weren't sure what they could do about it, what they could afford to do about it."

The GHI team included Marcial Blondet, Ph.D., the chair of civil engineering at Pontifical Catholic University, who developed the novel approach of using geomesh—a strong polymer netting more commonly used to reinforce elevated earthen berms—to provide external reinforcement to the school's adobe walls. Other team members came from Stanford University and the Lima-based nonprofit Estrategia. To watch a video of the project, click here: http://www.geohaz.org/projects/peru.html.

Adobe buildings have the reputation of being death traps during earthquakes, according to Greg Deierlein, P.E., Ph.D., F.ASCE, a structural engineering professor at Stanford University who helped design and plan the project and advised a team of Stanford and Pontifical students who worked in Chocos. But adobe remains a popular building material in rural Peru because it is locally obtainable and an effective insulator against wind, temperature, and sound. "But seismically, it's horrible, because it's very massive and it's weak," Deierlein says.

Geomesh is applied to both the interior and exterior walls. Courtesy of GHI/Stanford/PUCP

The school retrofit was a complex project. The roof, windows, and doors were removed to more effectively cover the structure with the mesh, which was applied to both the interior and exterior faces of the walls, which are 16 in. thick and 10 ft high. Workers then drilled small holes through the walls and used nylon connectors to fasten the internal mesh to the external mesh, anchoring both to the walls at multiple points.

The mesh was folded over the tops of the walls and anchored there by a reinforced-concrete ring beam, 16 in. wide and 6 in. thick. That ring beam not only anchors the geomesh but also prevents out-of-plane failures of the walls during an earthquake, Deierlein says. At the bottom of the walls, workers dug footers 6 in. wide and 12 in. deep on both sides of the existing rubble footers and anchored the mesh there.

“Just to get materials to this village is very hard,” Deierlein says. “Aggregate and sand, they could get locally there, but we had to bring in the cement, geomesh, and reinforcing bars. We also had to bring in a small mixer and other tools. It’s not like you could get a Ready Mix truck to drive up. All of this was dug by hand. This is all very labor intensive.”

GHI hired local workers to install the mesh and allotted extra time to the project to ensure that the workers understood the project and techniques, said Veronica Cedillos, a project manager for GHI, in written responses to questions from Civil Engineering magazine online.

The geomesh covered, workers begin the new roof. Courtesy of GHI/Stanford/PUCP

“The majority of buildings in the village are one- or two-story adobe buildings,” Cedillos said. “Finding the right balance between conducting the construction in the most cost-effective and time-efficient manner, and also taking the time to ensure adequate training for the workers during the construction since we were using the school retrofit as an actual teaching tool, [was a challenge].”

“At some point we decided that ensuring the education of our construction workers, who could later retrofit other structures, was our priority,” Cedillos said.

Deierlein says that during a weak earthquake, a geomesh-reinforced adobe building would experience less damage than one without geomesh. During a very severe earthquake, the mesh would function “as a kind of a basket” that would hold the adobe inside. “Under a large earthquake the adobe would be heavily cracked and the building would be unusable, but it would not have collapsed,” Deierlein says.

The overall project cost $160,000, much of which went toward a public education campaign and continuing efforts to make sure the project serves as a model for other schools in Peru. The retrofit cost about $30,000 and included a new roof and new doors and windows, constructed by local tradespeople from the community.

Because Chocos is very remote and isolated—the village has no cell phone service and the 300 residents share a single telephone landline—GHI commissioned a survey of the residents to guide them as they prepared an education campaign.

The finished school is safer and more attractive. Courtesy of GHI/Stanford/PUCP

"Our big challenge was to create a project that would have a life beyond the retrofit of one school," Cedillos said. "Our project team thought a lot about this and designed the project accordingly—we developed a strategy that would maximize the impact of the project."

GHI developed training for children, homeowners, and construction workers that focused on creating both the demand for earthquake-resistant structures and the supply of local people who know how to construct them, Cedillos said.

"We also focused on documenting the training and construction work in Chocos, and developing materials that could be used for replication in other areas," she added. "Although it is too early to tell if this will succeed beyond the one school retrofit, we have seen some signs that suggest it will."

GHI selected Chocos not only because it has an adobe school and a prevalence of adobe homes, but also because the community indicated a willingness to be active participants in the retrofit.

"We also conducted fun activities for the community during our time in Chocos, such as movie nights, when we talked about our project objectives and showed short videos promoting school earthquake safety before showing a fun movie for the children," Cedillos said. "The community really enjoyed this. In general, working on a project that benefits one of the communities' most vulnerable groups—schoolchildren—helps in terms of receiving support from the entire community."

Residents are excited about the retrofit, Deierlein says. "It's not only safe, but it looks a lot nicer than it did when we started. There was a tremendous amount of enthusiasm."

The project caught the attention of the Peruvian government, which sent Nora Chacon Delgado, the rural housing coordinator at the Ministry of Housing, to a ceremony marking the completion of the project. "She is particularly charged with looking at what the central Peruvian government does for these rural areas. And she was quite impressed with the project," Deierlein says.

The project was funded by grants from the Swiss Reinsurance Company, the Thornton Tomasetti Foundation, and GHI's Ohya Memorial Fund, which was established in memory of Satoru Ohya, a generous donor to GHI and a founding member of GHI's Board of Trustees.