Going vertical: Fleeing tsunamis by moving up, not out

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Damaged mosque and surrounding area in Banda Aceh, Indonesia, after the 2004 tsunami.

(PhysOrg.com) -- In the minutes after a strong earthquake struck offshore of the Indonesian city of Padang on Sept. 30, fears of a tsunami prompted hundreds of thousands of residents to evacuate the coastal city. Or try to.

The traffic jam resulting from the mass exodus kept most of them squarely in the danger zone, had a tsunami followed the magnitude 7.6 temblor. Stanford researchers who've studied the city have concluded that fleeing residents would have a better chance of surviving a tsunami if instead of all attempting an evacuation, some could run to the nearest tall building to ride out the wave.

It's called "vertical evacuation" and could save thousands of lives, but only if the city's buildings are reinforced to withstand both earthquakes and tsunamis.

Residents of Padang are trained to immediately evacuate to higher ground when they feel an earthquake. About 600,000 of the people in Padang live less than 5 meters above sea level, in the "Red Zone" for tsunamis. They have only about 20 minutes to evacuate, but on Sept. 30, it took them several hours.

"In the event of a tsunami, hundreds of thousands of people would be at risk and could have been killed, all because they couldn't evacuate fast enough," said Greg Deierlein, professor of civil and environmental engineering. Indonesia is at high risk for a large tsunami, Deierlein said, and horizontal evacuation strategies alone - by motor vehicle or foot - are clearly not adequate.

Deierlein and some Stanford students are investigating how to build or retrofit buildings to withstand both the earthquake ground shaking and tsunami inundation waves of 15 to 25 feet. Deierlein led a reconnaissance team of engineers and scientists to Padang, in Western Sumatra, nine days after the September earthquake to examine how buildings fared.

"It was like a big living laboratory," he said. "We were able to see how buildings performed and how the city reacted to the threat of a tsunami." During his visit, he was surprised by how many modern buildings collapsed.

"Existing buildings can be strengthened to perform better under future earthquakes and tsunamis," he said.

Deierlein, the John A. Blume Professor in the School of Engineering,

will present this work Dec. 15 at the American Geophysical Union meeting in San Francisco. The reconnaissance team he led was organized through the multidisciplinary Earthquake Engineering Research Institute, a nonprofit society of technical professionals, and supported by a grant from the National Science Foundation.

Though designing a brand-new building to withstand a tsunami would provide optimal protection from the onslaught of waves, it is often more economical to retrofit.

To retrofit buildings, engineers turn to computer models that combine principles of geophysics and structural engineering. The models can predict how a building will perform, depending on how strong the ground shaking is, how tall the tsunami waves are, the speed and direction of the waves when they hit and whether the flow is carrying debris, such as floating cars. The models also factor in the structure of the building - construction materials, the placement and strength of beams, columns and walls.

To enhance strength and stiffness, Deierlein said, engineers could make concrete columns or beams stronger and more ductile by retrofitting them with fiber-reinforced polymer composite overlays or concrete and steel jackets. Workers might add steel braces to the frame or construct walls that are reinforced to resist horizontal forces.

Walls in lower stories can be designed to break away under intense pressure from waves to reduce the stress on the building. These "frangible" wall systems, also found in hurricane-resistant buildings, are similar to windows that are designed to pop out under pressure. "It's like wind blowing on a building," Deierlein said. "Once windows pop out, wind can go right through."

Another important consideration is the foundation, which should be

protected from water that scours around the building. A tsunami could actually scour out so much of the ground around the building that it could be destabilized and fall over. Diversionary walls and berms could reduce this risk.

There isn't a single magic formula, Deierlein said; instead, buildings have to be treated on a case-by-case basis. Given the high cost of retrofitting, some buildings deserve more attention than others. "The design depends on the everyday function of the building," he said. "It's OK if a warehouse gets damaged, but an emergency response center, a large school or large hotel could be used as an effective refuge place during tsunamis and should be designed to a higher performance level."

To implement the latest research findings in developing countries, Deierlein and Stanford's Blume Earthquake Engineering Center are partnering with the Stanford chapter of Engineers for a Sustainable World, a national nonprofit organization linking students with professionals, and a Palo Alto nonprofit organization called GeoHazards International, which aims to prepare developing countries for natural disasters.

They are collaborating with Indonesian government agencies to suggest recommendations for building design and educate engineering students at Andalas University in Padang. "We're stepping up our efforts after the latest earthquake," Deierlein said. "Working with the Andalas University is a key way to transfer knowledge and technologies to the future generation of engineering professionals in Indonesia."

One challenge is training people to think about vertical evacuation. "Their instinct is to flee inland," Deierlein said. "So we have to figure out how to educate people to have faith in buildings." Most people see at most one tsunami in their lifetime, so they must rely on training rather than personal experience to change their habits.

Another approach is to make the most of people's instincts. "We're trying to understand what type of structures people would feel safe going to," said Veronica Cedillos, a structural engineer and project manager at GeoHazards International. "For example, we heard about a lot of people going to mosques after a tsunami, so that's definitely one of the main types of building we've been exploring as potential evacuation sites."

No matter the strategy, Deierlein has faith that people in Padang will rise to the challenge. "Developing countries have one advantage: They struggle all the time to survive," he said. He recalls visiting a hospital while in Padang and asking if the emergency generator worked. The answer: "Of course. We use it several times a week."

"I was impressed with the resiliency of the city," Deierlein said.

Still, he knows it's an uphill battle. "Developing countries have a long way to go to make the same improvements the U.S. has made in building design," he said. "It's important to reach out and look at problems facing developing countries, and to see how research and education can contribute to solving those problems."

Source: Stanford University (news : web)