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NEWS FOCUS

REBUILDING:

From the Bottom Up

Sam Kean

Haiti needs robust buildings that cost little and are acceptable to locals. Can scientists provide them?

Rebuilding the cities of Haiti to withstand natural disasters seems both simple and impossible. Engineers in the United States, Europe, and Japan have known for decades how to buttress buildings against earthquakes. The 1989 quake near San Francisco, California, for example—although it had the same magnitude as the Haiti tremor (7.0)—killed only 63 people. But Haiti simply doesn't have the money to adopt first-class solutions. Although various governments pledged to support Haiti over the next decade at a meeting in Montreal, Canada, in late January (Haiti is seeking $3 billion), Haiti has very little time to develop a rebuilding plan. With perhaps 170,000 dead and most survivors living outdoors and scared to enter standing structures, Port-au-Prince cannot wait. Nevertheless, scientists do see quick and cheap ways to rebuild—if Haiti is willing and able to accept foreign ideas.

Long vulnerable to disaster, Haiti has seen the danger grow in recent years, says Pierre Fouché, a Haitian citizen studying at the University at Buffalo's graduate school and, he says, one of Haiti's few earthquake engineers. Jobs drew millions to Port-au-Prince from rural areas, and the crowding forced people to build homes on dangerous slopes or unstable wetlands. He says the government lacked the power to dissuade anyone: "You just select a place to live and put up a house there, and no one is going to say anything."

Time out. Pierre Fouché, a Haitian earthquake engineer, aims to help rebuild his homeland quickly.

CREDIT: UNIVERSITY AT BUFFALO

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Compounding that problem, the buildings themselves are made of concrete that's heavy and brittle, the worst combination in an earthquake. People also tend to skimp on reinforcements like rebar, partly because no one in Haiti enforces building codes, Fouché says. Even when people do try to build safe houses, they cannot always trust the material they buy: There are already reports of people wrenching steel out of fallen buildings after the earthquake, bending it straight, and reselling the brittle, compromised rods.

Buildings toppled for less censurable reasons, too. Some were designed to withstand a more common natural threat, the sheer force of hurricane winds, not the back-and-forth shaking of earthquakes. Hurricane winds also produce a lift force that can pull rooftops off. Heavy roofs were therefore popular, but they became deadly during the quake. Perhaps most poignantly, people in Haiti saw modern concrete houses as a status symbol and aspired to have one. Indeed, the earthquake devastated both upper- and lower-class neighborhoods in Port-au-Prince. Both the shanties and the presidential palace fell.

New ideas

Much research into earthquake-resistant buildings today focuses on fine structural damage—research almost too sophisticated to apply to Haiti. Before he began developing ideas for cheap homes in seismically vulnerable countries, John van de Lindt, a civil engineer at Colorado State University, Fort Collins, studied topics such as how to alter the patterns of nails in wooden houses, mostly to prevent small frame shifts. He admits, "In Haiti, this stuff is overkill. You're basically trying to prevent collapses."

Some engineers want to rethink the basic materials used in developing countries. Darcey Donovan advocates replacing concrete walls with load-bearing straw bales. Her nonprofit group, Pakistan Straw Bale and Appropriate Building, erects 7.3-m-by-7.3-m houses in northwest Pakistan, which was ravaged by an earthquake in 2005. The bales are stacked and bound together top to bottom with a fishnet, which keeps them from slipping apart during shaking, then plastered over. Her team has built 11 houses so far, with six more coming. The design recently survived, with minimal damage, a violent test on a shake table, a large platform that simulates earthquakes. Because the tough, fibrous plants used for straw are ubiquitous, Donovan believes the bale design could easily be exported, and her team is discussing traveling to Haiti.

Donovan would like to eliminate concrete, but other engineers don't mind it, provided people use it safely. James Kelly, professor emeritus of civil engineering at the University of California, Berkeley, expects people in Haiti to continue building with concrete because it's cheap and easy to shape into blocks, and because deforestation has left few other materials. So Kelly focuses on keeping concrete buildings upright with rubber isolators to absorb shocks.

Many buildings in California and Japan sit on hundreds of rubber pads that absorb seismic energy by deforming, as opposed to cracking or shifting. A building on a rubber foundation essentially shakes independently of the ground and at a slower frequency, which helps brittle walls survive intact. But because isolators are usually custom-made and contain steel, they cost up to $10,000 apiece. Kelly designed cheaper isolators for a few hundred dollars, with embedded carbon fibers instead of steel. Carbon preserves the material's strength but makes it easy to mass-produce and cut into strips, which can be used in the foundations of small homes.

Van de Lindt works on a similar isolator design, but with recycled rubber tires instead of strips. And beyond redesigning walls and foundations—which only help new homes—Van de Lindt wants to retrofit existing homes. He says that drilling holes into concrete walls and inserting bamboo buttresses 1.3 meters long would keep many modest-sized homes in developing countries standing during quakes. This isn't sophisticated science, "it's more a social question," van de Lindt acknowledges: "Can we provide fixes that may not be perfect but are much, much better than anything they have now?"

One more ride. Old tires can cheaply insulate small concrete homes from the shaking of earthquakes.

CREDIT: COLORADO STATE UNIVERSITY

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In addition to rethinking building designs in Haiti, scientists are studying risks in the land itself. Marc Levy, an environmental management expert at Columbia University, was in Port-au-Prince when the earthquake struck. The building next door toppled, and he saw walls fallen over onto cars and pedestrians. He now worries about a secondary disaster: landslides, which usually happen during the rainy season starting in May. "The pattern of risk is going to shift," he says. "Areas not due to experience a catastrophic landslide for a decade" may have "moved to the top of the queue because of the loosening of the soil."

To address concerns like these, a team led by Brady Cox, a civil engineer at the University of Arkansas, Fayetteville, who surveys disaster zones worldwide, is currently mapping the soil in Haiti. They're doing so with the most sophisticated equipment they could ship in. At each site, they plant a sensor in the ground, walk about 30 meters away, and begin banging on the ground with a hammer. The energy of the blows propagates through the soil, and the sensor records higher or lower readings depending on how compact it is.

Better than brick. A nonprofit run by Darcey Donovan (*center*) builds earthquake-resistant homes in poor parts of northwest Pakistan that rely on load-bearing straw bales for walls.

CREDITS: PAKSBAB

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Cox says two types of soils in Haiti are vulnerable to earthquake damage. First is wet, sandy soil, which shifts unpredictably because sand grains, when shaken, grow compact and squeeze water out into confined spaces. Water then builds up underground and erupts like a geyser as the pressure grows. Cox suspects that this process opened the rifts along Port-au-Prince's harbor. Second is softer soil like clay, which shakes violently when the energy waves from an earthquake, straitjacketed in stiff bedrock underground, suddenly emerge in the softer material. Cox is mapping these types of soil not to tell Haitians where to avoid developing as much as to provide sorely lacking information. "We have the ability to design [buildings] for all these soil types," he says. "You just have to understand what type's there."

Small window

Even if scientists hit on a perfect design, other challenges remain. People must actually use the design—and quickly.

Georg Pegels, a civil engineer at the University of Wuppertal in Germany, has helped spread safer designs in Iran that rely on diagonal steel beams. Iran lost 30,000 people to a 2003 earthquake and experiences quakes of magnitude 6.0 or greater many times a decade. Despite the danger, Pegels says people often resisted living in his buildings for aesthetic reasons: They didn't like homes different from their neighbors'. Allowing artists to decorate the buildings helped convince people to accept them, he notes.

Pegels smartly concentrated on building schools, which gets many people in the community, including the next generation, comfortable with the design. His team has built more than 30 schools so far. In Pakistan, Donovan adds, people actually embrace new designs if they see them as status symbols. Some beneficiaries "think of [a straw-bale house] as high technology because it's earthquake resistant," she says. "It's all how it's presented."

Pegels also discovered that people often fear that inept or corrupt workers will cheat them out of the safe but expensive materials they pay top price for. (He mentioned cases of people putting steel in wet cement, showing the reinforcements to customers, then secretly pulling the metal out before the cement sets.) So his team builds steel frames at a trusted local factory and ships them to the site intact. This allows people to see they are getting a safe house. And unlike fully prefabricated homes, it also preserves jobs for locals, who fill in the masonry around the skeleton.

Scientists can foresee disaster in many seismically vulnerable countries: Iran, Turkey, Indonesia, China. But Haiti's acute need for housing presents a special challenge. Fouché fears his fellow Haitians will fall back on whatever design is most expedient: "If nothing is done quickly to set a new framework, the people there are going to do the same thing," he says. "They think, 'A big earthquake just happened, so there isn't going to be another one for a while.'"

Fouché knows there's a short time to establish the new framework. He has not visited Haiti since the earthquake but hopes he will have a chance to return after he has his degree and finally help Haiti build properly.

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