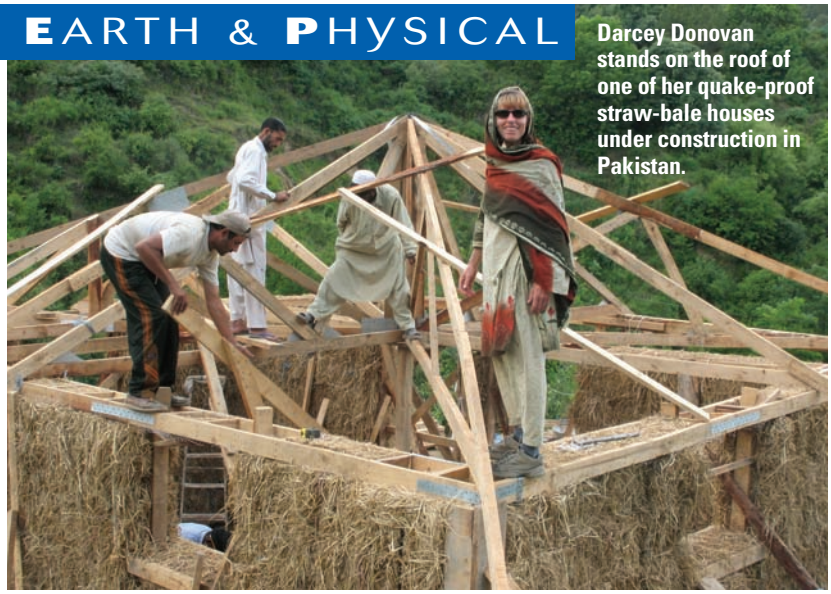

Darcey Donovan stands on the roof of one of her quake-proof straw-bale houses under construction in Pakistan.

By Stephen Battersby

# House of Straw

## It shivers. It shakes.

## But no earthquake can knock it down.

The little house looks doomed. It's about to endure vibrations as violent as those of the biggest earthquakes. Its walls aren't made from resilient steel or reinforced concrete. They're made from straw.

Darcey Donovan is holding her breath. She led the team that designed the house, and a lot hangs on whether it can withstand some fearsomely powerful tremors. Donovan's charity, Pakistan Straw Bale and Appropriate Building (PAKSBAB), is constructing similar straw houses in a region of northern Pakistan that a huge earthquake hit in October 2005.

That quake was one of the deadliest in history, killing about 100,000 people. At the time of the quake, most of those people were in their homes—homes that collapsed. New buildings are going up, but most are as fragile and dangerous as the ones that were knocked down. Donovan wanted to find an alternative design that's strong and cheap. "So it's enough to save their lives, but it's affordable," she says.

In California, Donovan had already used bales of straw to build houses that are designed to survive earthquakes. But few of those homes get their strength from their straw walls. They rely instead on a sturdy but expensive frame of wooden beams, posts, and cross braces. Donovan's aim was to find a simpler, cheaper design for the people of Pakistan.

### FAULT TO BLAME

To defend yourself against an earthquake, you need to know what you're up against. A quake begins when an underground *fault*, a fracture in Earth's crust, fails. Rocks on either side suddenly slip past one another, and the motion sends seismic waves through the ground.

Some seismic waves are relatively safe because they shake the ground *vertically* (up and down). Ordinary buildings are designed to support their own weight, so usually they can cope with vertical forces. But other seismic waves called

In Pakistan, laborers harvest wheat and carry the straw to a bale-making facility.

*shear waves* shake the ground from side to side. That motion can be destructive because few buildings are designed with horizontal forces in mind.

A building shaken by shear waves is like a car with an indecisive driver who keeps changing from forward to reverse and back again. The car is constantly *accelerating*—changing velocity—first in one direction, then the other. During an earthquake, that acceleration can't be changed. A house has to move back and forth with the ground or else it will come off its foundation.

What can be changed is the mass of a house. The destructive force felt by a house is the result not just of acceleration but also the house's mass, because force equals mass times acceleration (F=ma). Many buildings flattened by the Pakistan earthquake had massive walls and roofs made of rock. So Donovan's house has a smaller mass—a lightweight roof and lightweight walls made of straw.

The walls of Donovan's house are also remarkably strong. Stacked bales of straw are wrapped in nylon netting and sandwiched between layers of plaster. "We have a combination of materials working together," she says. That combination is designed to help the straw house resist both *compression* and *tension* during an earthquake. Compression is a force that squashes a material inward. The house's plaster and straw resist that. Tension is a force that stretches the material outward. The netting is good at resisting that.

980L


A PAKSBAB straw-bale house still stands after a violent shake table test.

So the whole building is both light and strong. In theory, that should make it earthquake-proof. To find out for sure, PAKSBAB built one of its houses in a lab at the University of Nevada, then lifted it onto an earthquake simulator called a shake table.

## STILL STANDING

Last spring, PAKSBAB began a series of tests, gradually stepping up the amount of shaking to see how much the house could take. "The last couple of tests were very exciting and dramatic," says Donovan. "The table itself is quite quiet, but the building makes noise as it's moving and the plaster is cracking and dust starts to fly around."

When the dust cleared, the little house was damaged but still standing. It had been hit with accelerations of up to 0.82 g. (One g is equal to the acceleration caused by Earth's gravity.) That's twice as fierce as the shaking recorded in 1994 in Los Angeles during one of the most destructive quakes in recent history. Donovan's straw house would have shrugged it off.

Donovan's charity can build a 7- by 7-meter (23- by 23-foot) house for about $2,500, which is half the price of an earthquake-resistant house made of concrete. The house is also well insulated, fire resistant, and vermin-proof, and is made with local, environmentally friendly materials.

Since May 2006, PAKSBAB has put up 11 straw buildings. It has plans for up to eight more, all funded by private donors. That may not sound like much considering that 600,000 buildings were destroyed by the 2005 quake, but the project is still young. "I would like this to happen on a really large scale," says Donovan. **CS**

**Straws bales are stacked on a gravel foundation; a door and a roof are added; and the house is ready to be covered in plaster.**

All photos: PAKSBAB.com