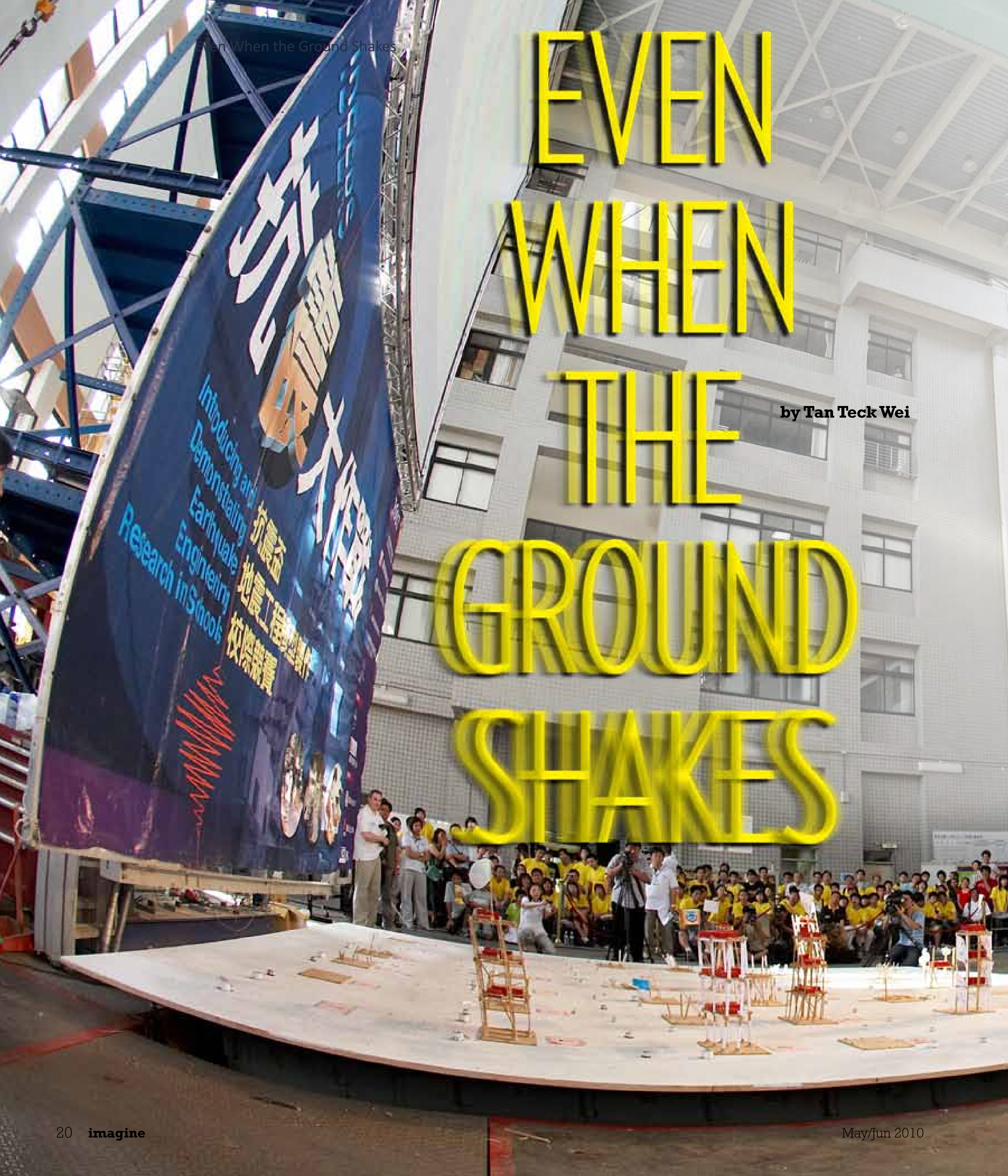
Even When the Ground Shakes

by Tan Teck Wei



Engineering Better Buildings through IDEERS

The recent earthquakes in Haiti and Chile remind us that earthquakes remain as unpredictable and dangerous as ever. One thing we know for certain is that there will be more.

Earthquakes occur when pressure inside the earth's lithosphere causes its tectonic plates to slip out of position. Waves of vibration from within the earth create complex vibrations on its surface, often resulting in collapsed skyscrapers, crushed houses, and demolished roads and bridges. Families lose homes, possessions, and all too often, loved ones.

The Chilean earthquake was 500 times more powerful than the Haitian quake, but because of differences in building construction, Haiti suffered far more damage. While we can't accurately predict when or where earthquakes will happen, we can try to make structures earthquake-proof.

In 2001, the National Centre for Research on Earthquake Engineering in Taipei, Taiwan, established an international competition to introduce students to earthquake engineering. The annual competition, Introducing and Demonstrating Earthquake Engineering Research in Schools (IDEERS), challenges students to design and construct model buildings that can withstand forces equivalent to those of an earthquake.

Building Engineers

I've always been drawn to unique competitions, so when my geography teacher announced that Singapore Polytechnic had invited area high schools to participate in Singapore's National Earthquake Competition—which serves as a preliminary contest to IDEERS—I was interested. At a competition briefing at Singapore Polytechnic, structural engineering students presented designs used in well-known buildings and demonstrated how they integrated the ideas into their own projects. I found this combination of theory and application especially fascinating, and decided to organize a team with two friends from my geography class.

We would have two weeks to construct a model building out of wooden sticks, glue, and rubber bands, conforming to a strict height limit as well as restrictions on the distance between floors. During the competition, the model would be secured to a wooden base and tested under the rigors of a simulated earthquake. The goal was to build an efficient model—relatively light, yet sturdy enough to withstand an earthquake.

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IDEERS teams' structures set up on the shaking table.

In Taiwan, Teck Wei's team visited the Shih-Kang Dam, which was severely damaged in a 1999 earthquake.

The Raffles Institution's 2009 IDEERS team at the 921 Earthquake Museum: Benjamin Lee, Mathias Ng, Hubert Teo, Li Yiming, Tan Teck Wei, Samuel Ching, and teacher Yuen Kah Mun.

Forces of Nature

The horizontal and vertical forces that shake the earth during an earthquake are called *translational* forces. *Torsional* forces cause differential rotation within individual buildings. Designing buildings that can withstand an earthquake must take these forces into account.

Over the years, various methods and designs have been tested in the field of earthquake engineering with the goal of keeping a building upright even when the ground shakes and all else is falling. *Hydraulic dampers*, pistons filled with a viscous fluid that minimizes vibrations, are now employed in most skyscrapers. These dampers allow steel frameworks to move laterally during an earthquake, absorbing energy and minimizing damage. Similarly, *base isolation structures* allow a building to move independently of its foundations during an earthquake to protect the building's structural integrity.

IDEERS participants would learn about these concepts through interaction with structural engineers, visits to earthquake-damaged regions, and of course, the design and creation of their own earthquake-proof structures.

We began by constructing a series of wooden models, experimenting with structural and design features ranging from exotic crossbeam elements to unusually large, glue-coated columns.

To determine the intensity of an earthquake, geologists use the *gal*, a unit of measure that describes local variations in the acceleration of gravity. The gal, named for Galileo, is a unit of acceleration: 1 gal is an acceleration of 1 centimeter per second squared (cm/s^2). During the competition at Singapore Polytechnic, we secured our final model to a "shaking table" powerful enough to simulate earthquakes with accelerations of up to 800 gal—equivalent to that of the recent earthquake in Haiti.

Our model withstood 500 gal of acceleration. Eventually, its columns broke near the base board, causing it to collapse and break apart. We finished in the middle of 20 teams, well enough that Singapore Polytechnic agreed to mentor us as we prepared for IDEERS.

Shake, Rattle, and Roll

Watching our early models twist, shake, wobble, dance, and eventually break had been novel and fun. In preparation for IDEERS, we applied the knowledge gained from these tests to successive models. We often worked late into the night, bonding over a pizza dinner in the eerily quiet school and the knowledge that we had to face homework when we finally arrived home.

Ultimately we created 10 models, varying elements such as column thickness and the distance between each floor to achieve a sturdy model that was as lightweight as possible. While our final model was based on competition guidelines, it also reflected our own methods and ideas.

The guidelines required that our building have an L-shaped base, but a few days before we were to leave for Taiwan, we realized that we had misinterpreted the rules. The organizers had already marked the L-shape on the competition base boards on which we would mount our models. This meant that we could only mount our model horizontally within a certain area, instead of using the entire base board. Thus, we had to tweak some dimensions of our model at the last minute, leaving us no time to test our final model in Singapore. We reassured ourselves with the knowledge that this last model was by far our best.

We were accompanied on the trip to Taiwan by teachers and students from other teams, as well as our coach and mentor, Dr. Tao Nengfu, a professor in earthquake engineering from Singapore Polytechnic. Once there, we took field trips to such places as the ruins of the Shih-Kang Dam, destroyed by a 1999 earthquake, and an earthquake engineering museum built around the crumbled remains of a high school destroyed by the same earthquake. Standing in that spot, I felt incredibly fortunate to live in a country that is not on the boundaries of major plates.

We also toured the Taipei 101, one of the world's tallest earthquake-proof buildings. Its 66-story tower contains 36 massive columns and a series of sophisticated dampers. Most buildings in Taiwan are equipped to withstand earthquakes, but some older buildings have yet to be retrofitted with the relevant technology, which is costly. To us, the Taipei 101 stood as an impressive example of earthquake engineering.

Focus and Determination

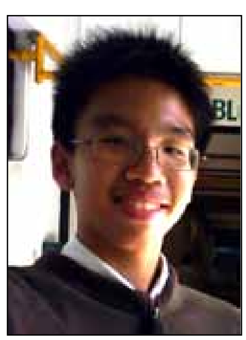
By the time we had completed our field trips, teams had arrived from all over the world. We would construct our models on the first day of the two-day competition; on the second day, we would test them.

On day one, we entered a giant lab where real earthquake engineering technologies are tested. The shaking table, designed as a testing bed for small houses and buildings, was huge—nearly the size of a football field and at least five stories high. Judging would be based on a simple equation: The facilitators would note the maximum acceleration the model withstood—ranging from 0 to 1,000 gal—and then divide that number by the model's weight.

We raced to complete our model with as much precision as possible. Through sheer determination and focus, we managed to finish within the six-hour time limit, with better workmanship than before. The next day, we attached our model to the shaking table, unsure whether our months of hard work would pay off. As the table shook, so did we. With every twist the model made, we squirmed in our chairs. The judges examined the models to determine if they had deformed more than 15 percent, if more than half the model's legs were no longer connected to the base board, or if they had partially or entirely collapsed. Those that were too deformed to continue were eliminated.

Our model made it past the final round, but two of its columns had been dislodged and it was leaning perilously to one side. The judges ranked the models by applying the efficiency ratio. A Taiwanese team won the top prize in the high school category—20,000 Taiwan dollars (about $628 USD)—with a model that was not only light, but also strong: It managed to survive all the rounds of shaking intact. We were disappointed that we hadn't won, but we tried our best and we learned a lot, and that was what mattered to us most.

Participating in IDEERS has helped me appreciate the magnitude of our insignificance compared to the forces of nature. This brief introduction to structural engineering has only piqued my interest more. I hope to mentor teams in future national earthquake competitions, and perhaps I might study structural engineering at a university one day. **i**



Tan Teck Wei, 16, is in Secondary 4 at the Raffles Institution, the oldest school in Singapore, where he is captain of his school's debate team. When he isn't playing soccer or basketball, you'll likely find him reading a book somewhere on campus.

To learn more about IDEERS, visit www.ideers.bris.ac.uk.

Teck Wei would like to acknowledge the contribution of his fellow teammates from IDEERS in the writing of this article. They are Samuel Ching, Benjamin Lee, Li Yi Ming, Matthias Ng, and Hubert Teo.

VEOCTORSTOCK/ SHUTTERSTOCK

MICHAEL APEL

BIOMIMICRY

by Amy Dusto

Nature's biggest fans right now might be engineers. Looking to what eons of evolution have already figured out, they are designing technologies to solve all sorts of problems with the inspiration of nature—an approach known as biomimicry.

Maple Tree Seeds → Lightweight Aircraft

Caught in the wind, the winged seeds of maple trees trace helices in the sky, often landing far from where they began. Engineers have translated the properties that make these lightweight structures so efficient at flying into their own winged creations.

At the University of Maryland, a team inspired by these "helicopter" seeds has created a micro-surveillance aircraft—the smallest version of which weighs only 38 grams and measures 18 cm at its longest. With a single wing based on the maple seed and an additional rotor-like component that engineers put into the body, the aircraft can hover and move in directed flight. In addition to military applications, such a device could be used to monitor forest fires or to aid in search and rescue operations.

EVAN ULRICH

Gecko → Stickybot

The quadruped wall-climbing robot developed in the laboratory of Sangbae Kim at Stanford University looks suspiciously like a gecko. Indeed, the Stickybot was designed that way.

Able to climb smooth vertical surfaces such as glass and whiteboards, the Stickybot uses an adhesive based on the small-scale properties of gecko digits that make the creatures such impressive climbers. This "gecko tape" is self-cleaning and directional, so actuators in the robot can control the direction in which the adhesive force is applied.

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