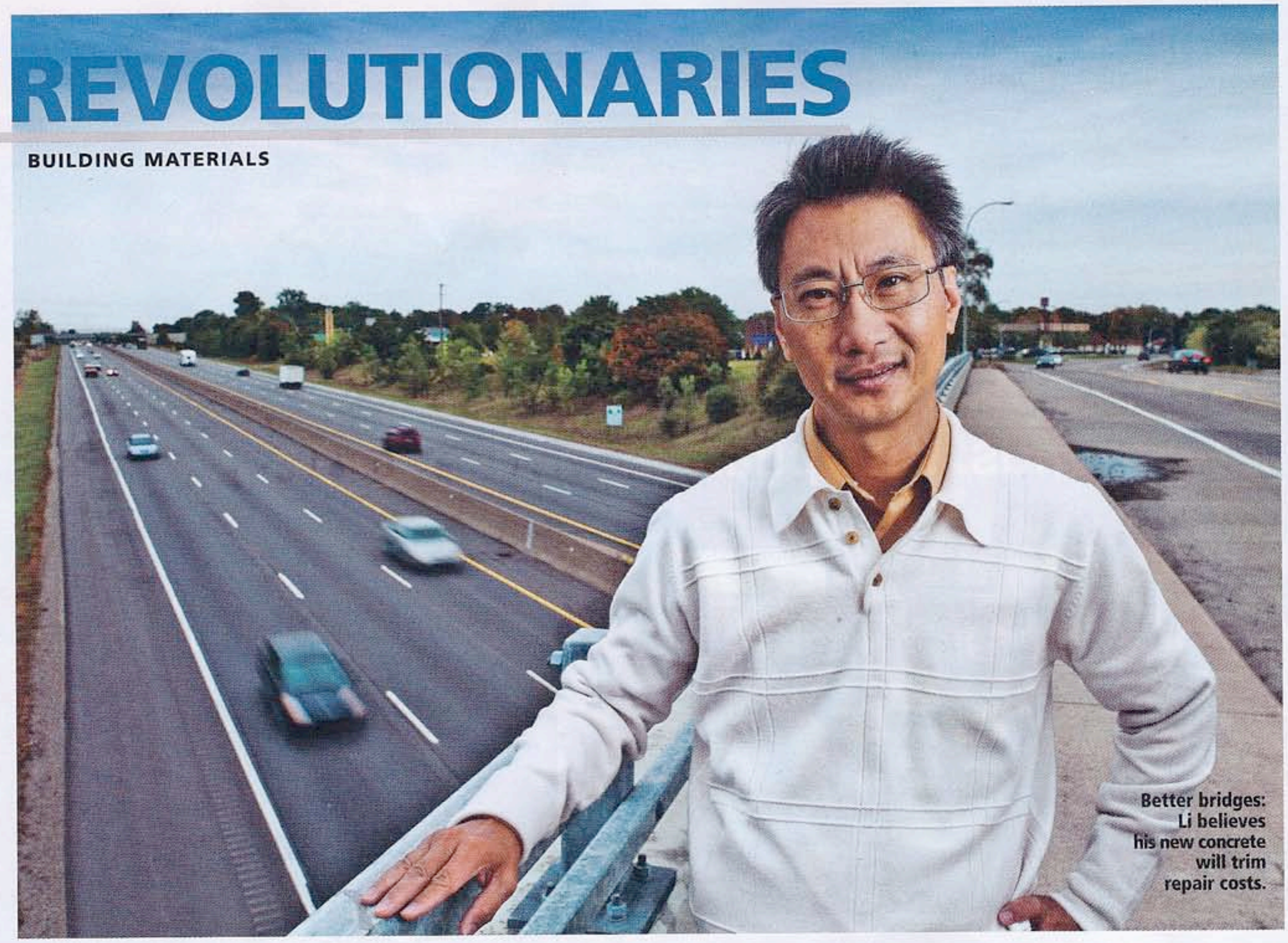
BUILDING MATERIALS



Better bridges: Li believes his new concrete will trim repair costs.

JOE VAUGHN FOR FORBES

Self-Healing Concrete

Civil engineer Victor Li designed a bendable concrete that repairs its own cracks. By Anna Vander Broek

AMERICA'S BRIDGES ARE falling down. Victor Li says he knows a better way to build them. The civil and environmental engineering professor at the University of Michigan has invented a new kind of concrete that hardly ever cracks and, if it does, can repair itself.

A typical American bridge is built to last 50 years (and then only if it gets frequent roadbed replacements). Today the average age of U.S. bridges is 42 years. One-quarter of all bridges were deemed either structurally deficient or functionally obsolete last year by the U.S. Department of Transportation. In a March report the American Society of Civil Engineers gave U.S. infrastructure a grade of "D," reflecting delayed maintenance and chronic underfunding; it estimates that $2.2 trillion is needed over the next five years to bring that grade up to a "B."

"We have an increasing stock of deteriorating infrastructure, and maintenance work is not catching up with it," says Li, 55. "We can't fill that gap with money. The only way is new technology." He says his self-healing concrete will help tackle durability problems and reduce the cost of maintaining bridges and roads.

Last year the world swallowed up 3 billion tons of cement, the active ingredient in concrete, according to the Portland Cement Association. (Concrete's three other ingredients: gravel, sand and water.) Concrete has marvelous virtues, including a low cost and a high compression strength. Its main fault is brittleness. It needs steel inside for tensile strength.

On a bridge surface or road that mix of steel and concrete is trouble waiting to happen. Heavy trucks cause cracks, which let in water and salt, which turn the steel to rust, which causes the whole pad to crumble.

Li's self-healing concrete is based on a material he came up with in 1990 called engineered cementitious composite. It has some of the same ingredients as portland cement, except the coarser bits of the mix are replaced by microfibers. When the composite is stressed, it bends without fracturing. If it does crack, the cracks tend to be less than 50 microns wide—thinner than a human hair. These tiny cracks have the ability to heal themselves.

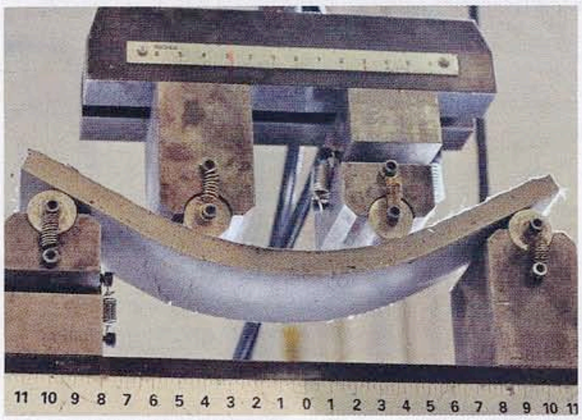
The healing process is similar to the way human skin repairs itself: A paper cut heals much faster than an inch-wide gash. When Li's concrete develops hairline cracks, the dry composite is exposed to the moisture in the air, which it absorbs. As it does, it "grows" new concrete, filling in the minuscule cracks. Meanwhile, calcium ions inside the cracked concrete mix with moisture and carbon dioxide from the air, creating a calcium carbonate material similar to what seashells are made of. This enables the concrete to regain its initial degree of strength.

"If self-healing concrete can minimize cracks, you should get a longer life and a more sustainable structure," says Andrew Herrmann, a partner at New York City infrastructure transportation consulting firm Hardesty & Hanover.

In 2002 Li debuted a precursor concrete material that was bendable (but not self-healing). This bendable concrete has been used in the core of several high-rise buildings in Japan—including a residential tower in Osaka completed this year—to absorb energy during earthquakes.

Li figures he's five years away from putting his self-healing concrete into bridges and roads. It needs to go through years of testing before it can be approved for use. A patent for the newfangled concrete was granted to the University of Michigan in August this year; Li and his former graduate student En-hua Yang were named the inventors. The university is currently in talks with building materials companies about licensing agreements.

When Li moved to the U.S. from his native Hong Kong in 1973, he wanted to invent a way to reduce construction noise. Growing up, he saw and heard the endless construction of an expanding Hong Kong. At Brown University he got undergraduate degrees in economics and mechanical engineering and, in 1981, a Ph.D. in solid and structural mechanics. While at Brown he became baffled by the fact that a country as wealthy as the U.S. had such run-down roads and bridges, especially compared with Hong Kong. That pushed him to find a better solution.



The precursor to Li's self-healing concrete: a bendable version.

Li's self-healing concrete would cost about three times more than the standard item, he says, but pay for itself in reduced repair work. He estimates that the Grove Street Bridge, which crosses highway I-94 in Ypsilanti, Mich. and was built with traditional concrete, will average $350,000 a year in maintenance, user and environmental costs—its so called "life-cycle cost"—over 60 years. The same bridge, if built with Li's self-healing concrete, ought to have a 50% lower life-cycle cost. That would add up to a savings of $11 million, potentially justifying a much higher initial price tag.

Armed with $9 million from the National Institute of Standards & Technology and $10 million from various sponsors, including the Michigan Department of Transportation, Li is working on his next project: a concrete that can not only heal itself but also tell you when it has been damaged. A concrete that can talk back to monitoring systems—that could be the ticket to getting an "A" grade on U.S. infrastructure. **F**

SEMICONDUCTORS

Storage For The Millennium

Tadahiro Kuroda has a memory chip with a 1,000-year expiration date.

By Anna Vander Broek

IF PEOPLE CAN READ THIS STORY A millennium from now, they may have Tadahiro Kuroda to thank. Kuroda, an electrical engineering professor at Keio University in Japan, has invented what he calls a "Digital Rosetta Stone," a wireless memory chip sealed in silicon that he says can store data for 1,000 years.

As technology changes, storage goes stale. Can your computer read your old $5^1/_4$-inch floppies? Data typically has to be put on new storage systems every 20 years or less for it to be accessible. The digital migration costs time and money. Storing and maintaining a digital master of a very high-resolution movie, for example, costs $12,500 a year; archiving a standard film costs $1,000 a year.

The Library of Congress' National Audio-Visual Conservation Center

Storing data for the very long term: electrical engineer Tadahiro Kuroda.

FAR LEFT: COURTESY OF THE UNIVERSITY OF MICHIGAN