MARVELS

CONCRETE EVIDENCE

WATER IS THE SUBSTANCE MOST WIDELY USED BY HUMANS. SECOND? CONCRETE, BELIEVE IT OR NOT. WELCOME TO THE EVER-EXPANDING WORLD OF HIGH-TECH CONCRETE.

BY DANIEL WEISS

PHOTO: AGENCE RUDY RICCIOTTI

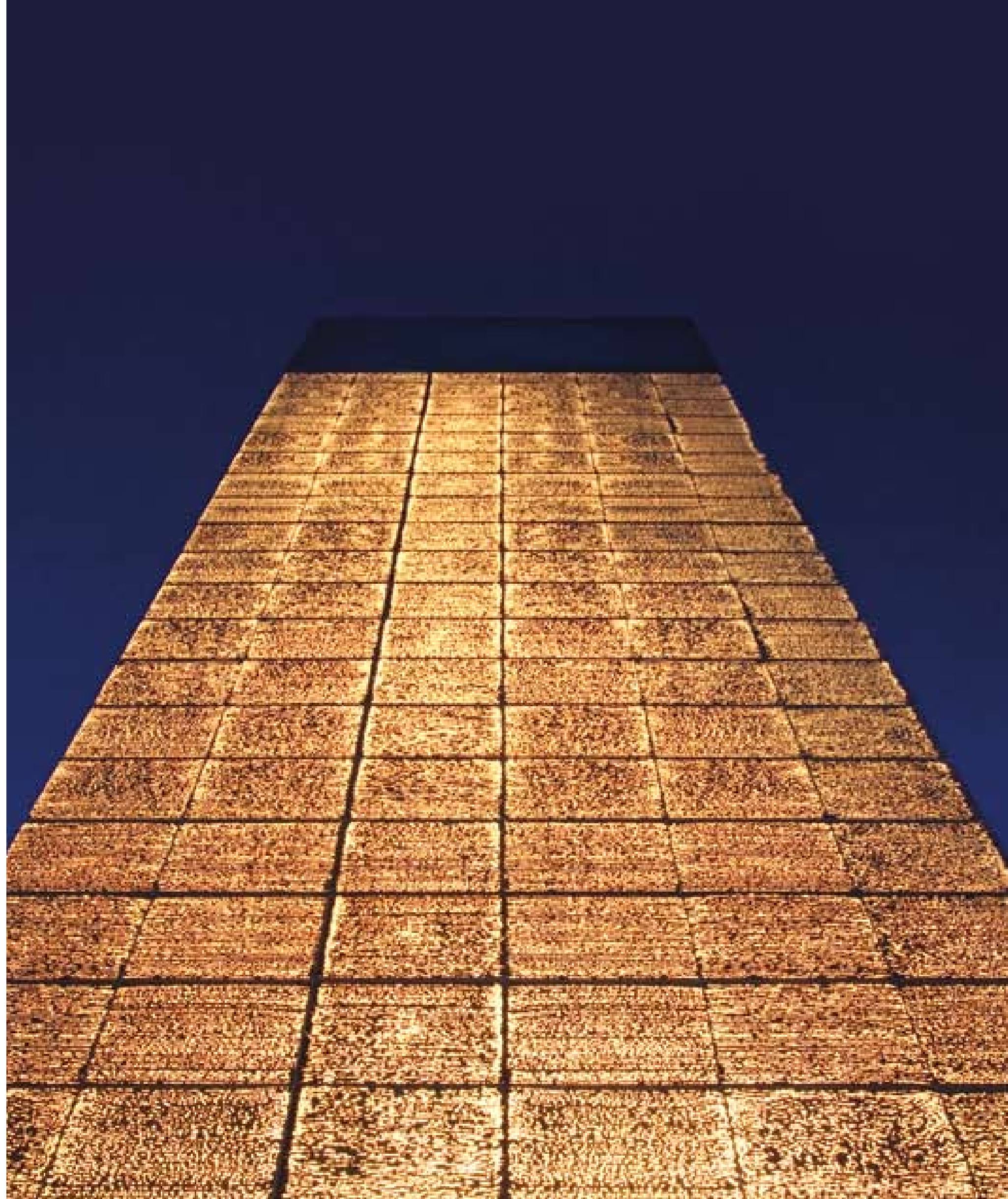
The basic modern recipe for concrete, developed in the early 19th century, combines Portland cement with water, gravel and sand to make a highly versatile building material. But it's not Earth-friendly. Concrete production is responsible for about five percent of all human-produced carbon dioxide. The culprit is a key step in the cement-making process, when limestone (calcium carbonate) is cooked at around 1,450°C to yield quicklime (calcium oxide). For every tonne of cement produced, about a tonne of carbon dioxide is released, half due to the heating fuel and half due to the chemical transformation.

Efforts to reduce the carbon footprint of concrete have included building more efficient kilns and replacing some of the cement with industrial by-products like fly ash (leftover from coal combustion), cement slag (from smelting iron ore) and silica fume (from semiconductor production).

Fly ash, which can replace up to a third of the cement in concrete, and slag, which can replace up to two-thirds, often make concrete stronger by forming cement-like bonds and moderating heat produced when the cement reacts with water. (In 2007, concrete fortified with fly ash and slag and used for the core of the Freedom Tower in New York City in the United States set a compressive strength record.)

The additives can also protect concrete from corrosion by reducing its permeability, which is why concrete used for bridge decks frequently includes silica fume.

THE ANCIENT ROMANS USED IT TO MAKE ICONIC BUILDINGS SUCH AS THE PANTHEON, AND THE EGYPTIANS MAY HAVE USED IT EVEN EARLIER FOR THE PYRAMIDS



NEW WORLDS IN CONCRETE

Several companies worldwide are going a step further by entirely replacing the cement in concrete. Zeobond, based in Melbourne, Australia, uses extracts from fly ash and slag as the basis for the binding agent in its E-Crete. The extracts become chain-like "geopolymers" with the addition of a base, a reaction that requires no heating. In all, E-Crete produces a fifth the carbon dioxide of conventional concrete, according to Peter Duxson, a chemical engineer and Zeobond's chief of operations.

Zeobond has four plants producing full-time, three in Melbourne and one in Queensland, Australia, and hopes to expand to eight next year. E-Crete has been approved for use in roads and pavements and is undergoing testing for use in bridges.

Eventually, Duxson would like to see it form the foundation of a skyscraper in a major first-world city - the ultimate test for concrete - but he would be satisfied if E-Crete helped pave the way for rapid urbanisation in the developing world. "The ultimate measure of the success of what we do is how many tonnes of cement we can make and how many tonnes of carbon dioxide we can abate," he says.

But modern tweaks and innovations are not just making concrete more Earth-friendly, they are taking it in a whole range of new directions.

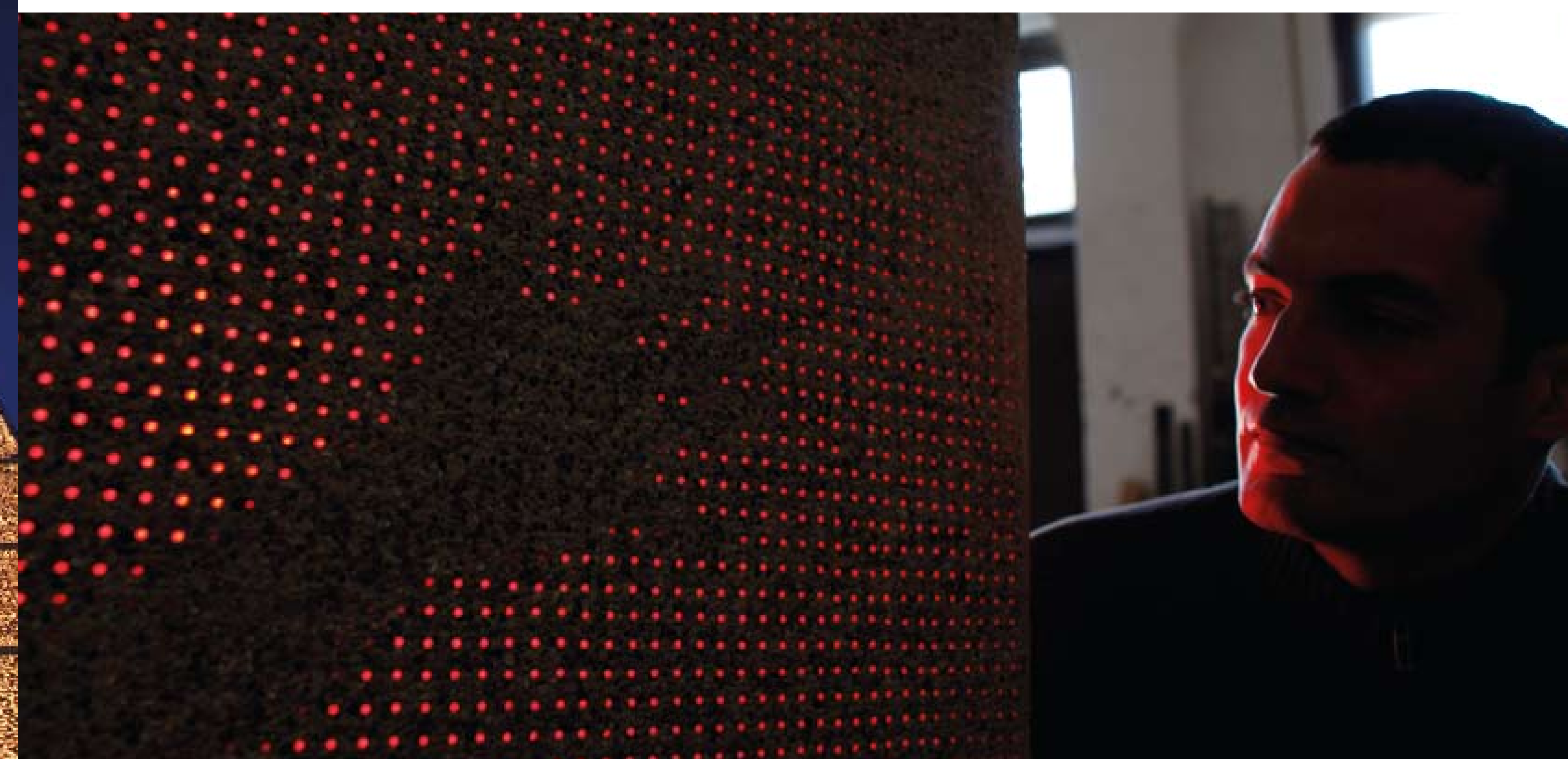
PHOTOS: COURTESY LITRACON; COURTESY LITRACON; REUTERS

LIGHT-TRANSMITTING CONCRETE

Hungarian architect Áron Losonczi dreamed of a combination of glass, concrete and light. The result is LiTraCon, concrete embedded with fibre-optic glass cables the width of a human hair that transmit light through stone. Losonczi has been producing the novel slabs in a small factory in the Hungarian town of Csongrád since 2004.

LiTraCon is made by hand, with layers of fibre-optic cables alternating with layers of concrete. "It's like a big lasagna," says Losonczi. In the end, two million of the skinny cables are distributed throughout each square metre of the finished product. The cables make up just four percent of the total volume, which is plenty to transmit the subtleties of light and shadow.

Designers have used LiTraCon in works like museum doors, monuments and tombstones. The operation is still quite small, producing a few hundred square metres per year, in part because of its high price: a square metre costs just over US$1,000. But Losonczi hopes demand will be spurred by a new, cheaper version: LiTraCon pXL, which uses plastic rods instead of fibre-optic glass and can be mass-produced.



Light-transmitting concrete, created by architect Áron Losonczi (opposite, bottom), was used in the Europe Gate (right) and the entrance to Museum Cella Septichora (opposite, top), both in Hungary.

HARD FACTS • **5.5 km^3:** *Approximate amount of annual worldwide concrete production.* • **Approx. 8,500 km:** *Length of Roman roads built from concrete.* • **16 million m^3:** *Amount of concrete used in the Three Gorges Dam, China.* • **3.44 million m^3:** *Amount of concrete used to build the Hoover Dam in the United States.*

POLLUTION-EATING CONCRETE

In his design for the Jubilee Church in Rome, Italy, commissioned to celebrate the 2,000th anniversary of Christianity, renowned American architect Richard Meier included three curved shells ranging in height from 17 to 27 metres. The shells, meant to resemble ship sails, were to be blinding white. In order to keep them from tarnishing, he had them built using a new concrete that helps break down airborne pollutants, keeping its surface free of grime while improving air quality.

The cement in the concrete - called TX Active and produced by the Italian company Italcementi - includes titanium dioxide particles. In reaction with the sun's ultraviolet rays, these particles speed up the natural oxidation of pollutants. As a result, Italcementi claims that substances such as "vehicle exhaust fumes, emissions from residential heating systems, industrial aromatic chemical compounds and pesticides" are broken down. A test by the company, in which a street was paved with the special concrete, found that some pollutants were reduced by up to 60 percent.

MODERN TWEAKS AND INNOVATIONS ARE TAKING CONCRETE IN NEW DIRECTIONS

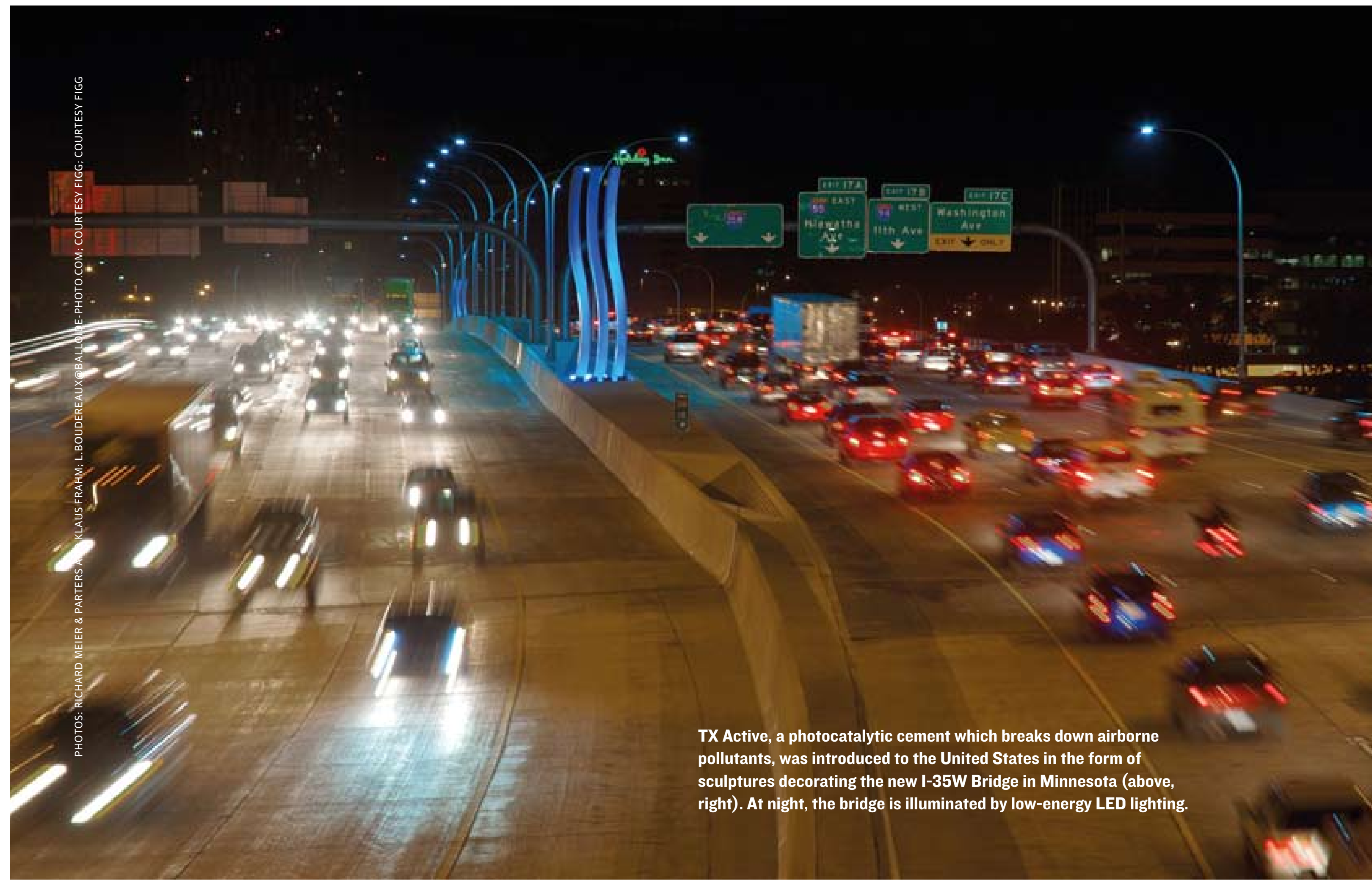
So how has the Jubilee Church held up in the years since its 2003 opening? "I just visited the building, and it looks as fresh and new today as the day it was constructed," Meier wrote in an e-mail from Rome during a recent trip. "The cement was a great innovation."

SUPER-STRONG CONCRETE

Concrete reinforced with steel bars is key to keeping the world's tallest skyscrapers standing. Now the French concrete company Lafarge has developed a line of ultra high-performance concrete called Ductal that is even stronger. Fortified with steel fibres that make up two percent of the concrete by volume, its compressive strength can be as high as 200 megapascals (MPa). This is much higher than conventional concrete, whose compressive strength is typically under 40 MPa, although high-strength varieties used in skyscrapers have measured as high as 131 MPa. Ductal also has substantial tensile strength, which is negligible in conventional concrete unless reinforced with steel bars.

French architect Rudy Ricciotti has used the new concrete's strength to attain a light and elegant look in a variety of designs. His 68-metre Pont du Diable footbridge in southern France, whose platform is a mere 3 centimetres thick, shoots across a chasm like a long girder without a single structural support.

To keep the sail-like shells of Rome's Jubilee Church (above, left) pristine, pollutant-destroying concrete was used. Could we use it for houses too? The Pont du Diable footbridge (above, middle) spans an amazing 68 metres without any support.



PHOTOS: RICHARD MEIER & PARTERS A... KLAUS FRAHM; L.BOUDEREAUX@BALLOIDE-PHOTO.COM; COURTESY FIGG; COURTESY FIGG

TX Active, a photocatalytic cement which breaks down airborne pollutants, was introduced to the United States in the form of sculptures decorating the new I-35W Bridge in Minnesota (above, right). At night, the bridge is illuminated by low-energy LED lighting.

17 MPa: *Typical compressive strength of concrete in residential buildings.* **28 MPa:** *Typical compressive strength of concrete in commercial buildings.*

RUDY RICCIOTTI USED A NEW TYPE OF CONCRETE TO ATTAIN A LIGHT AND ELEGANT LOOK IN A VARIETY OF DESIGNS

Take a walk across the Rainbow Bridge to reach Seonyu Island in Seoul, Korea. Made of Ductal, it resembles its namesake most when seen at night.

From 2003 to 2008, winter driving was slightly easier on the Roca Spur Bridge in the US state of Nebraska. The bridge hosted a demonstration of conductive concrete, which could heat up to keep the road free of ice and snow.

PHOTOS: E. JAE SEONG; BRETT HAMPTON; CORBIS

A planned rugby stadium in Paris, France, will feature a 30,000-square-metre web of concrete embedded with glass triangles hovering over the stands. The Museum of European and Mediterranean Civilisations in Marseilles, France, will be enveloped in a concrete lattice inspired by Islamic design styles. The new concrete is essential, Ricciotti says, in order to realise “such delicate and slender architectural works”.

CONDUCTIVE CONCRETE

Snow and ice cause accidents on roads and backaches for those who have to shovel pavements and driveways after every storm. Someday soon, there may be a new solution: pavement made from special conductive concrete that can be heated with an electric current.

This is the brainchild of Christopher Tuan, professor of structural engineering at the University of Nebraska in the United States. Steel fibres and sand-grain-sized carbon particles are mixed into the concrete, making it electrically conductive. Electrodes of angle iron or steel rebar are embedded in the concrete. Current runs through them, raising the pavement’s temperature to 7°C to 10°C, warm enough to prevent snow or ice from sticking.

You’d think a concrete canoe would sink, but there are even competitions centred on racing them.

For several years, Tuan ran a demonstration project on a bridge near his university and has now shifted to developing the system for use on private driveways and walkways. Ultimately, Tuan would like to use microwaves to melt the snow and ice, which he calculates will be seven times more efficient than electricity. “With microwaves, we can direct the energy straight to the ice and snow without heating the conductive concrete at all,” he says.

AND MORE

The list of concrete innovations goes on. Porous concrete allows water to drain right through the pavement rather than building up and causing hazardous traffic conditions. Self-consolidating concrete flows into small spaces without the time-consuming, expensive use of vibration machines. This is particularly helpful in getting concrete to flow past steel cables in heavily reinforced structures.

To demonstrate concrete’s versatility, teams of engineering students from countries including the United States, the Netherlands, Japan and Australia build concrete canoes and enter them in competitions. Winners are determined based on the crafts’ design and their performance in races. Concrete consultant Jay Shilstone, based in the US state of Texas, once met a man who had his business cards made out of a special kind of concrete. “They were no thicker than a normal card,” he says, “but they were strong enough and flexible enough that they could bend slightly.”

Shilstone adds that, in the future it may be possible to mix microscopic strain gauges into concrete so it would make a special sound when it is about to fail. “It would be like an air raid siren in a concrete building,” he says. ■