'Sensing skin' could monitor the health of concrete infrastructure continually and inexpensively

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In the MIT laboratory, researchers tested the "sensing skin" by attaching it to the underside of a concrete beam, then applying enough force to cause tiny cracks to form in the beam under one patch of the skin. Credit: Simon Laflamme, MIT

In 2009, the American Society of Civil Engineers (ASCE) assigned the grade "D" to the overall quality of infrastructure in the U.S. and said that ongoing evaluation and maintenance of structures was one of five key areas necessary for improving that grade. Since that time, federal stimulus funds have made it possible for communities to repair some infrastructure, but the field of high-tech, affordable methods for the continual monitoring of structures remains in its infancy. Instead, most evaluation of bridges, dams, schools and other structures is still done by visual inspection, which is slow, expensive, cumbersome and in some cases, dangerous.

Civil engineers at MIT working with physicists at the University of Potsdam in Germany recently proposed a new method for the electronic, continual monitoring of structures. In papers appearing in the *Journal of Structural Control* (December 2010) and the Journal of Materials Chemistry (April 2011) the researchers describe how a flexible skin-like fabric with electrical properties could be adhered to areas of structures where cracks are likely to appear, such as the underside of a bridge, and detect cracks when they occur.

Installing this "sensing skin" would be as simple as gluing it to the surface of a structure in the length and width required. The rectangular patches in the skin could be prepared in a matrix appropriate for detecting the type of crack likely to form in a particular part of a structure. A sensing skin formed of diagonal square patches (3.25 inches by 3.25 inches, for instance) would be best at detecting cracks caused by shear, the movement in different directions of stacked layers. Horizontal patches would best detect the cracks caused when a horizontal beam sags. The largest patch tested using the prototype reached up to 8 inches by 4 inches in size.

The formation of a crack would cause a tiny movement in the concrete under the patch, which would cause a change in the capacitance (the energy it is storing) of the sensing skin. Once daily, a computer system attached to the sensing skin would send a current to measure the capacitance of each patch and detect any difference among neighboring patches. In this way, it would detect the flaw within 24 hours and know its exact location, a task that has proved difficult for other types of sensors proposed or already in use, which tend to rely on detecting global changes in the entire structure using a few strategically placed sensors.

"The sensing skin has the remarkable advantage of being able to both sense a change in the general performance of the structure and also know the damage location at a pre-defined level of precision," said Simon Laflamme Ph.D. '11, who did this research as a graduate student in the MIT Department of Civil and Environmental Engineering (CEE). "Such automation in the health monitoring process could result in great cost savings and more sustainable infrastructures, as their lifespan would be significantly increased as a result of timely repairs and reduced number of inspections." Laflamme, worked with Professor Jerome Connor of MIT CEE and University of Potsdam researcher Guggi Kofod and graduate student Matthias Kollosche.

The researchers originally tested their idea using a commercially available, inexpensive stretchy silicon fabric with silver electrodes. While this worked in some of the lab experiments performed on both small and large concrete beams under stress, the material showed limitations in its installation because it was too thin and flexible for this use. The researchers have now developed a prototype of a sensing skin made of soft stretchy thermoplastic elastomer mixed with titanium dioxide that is highly sensitive to cracks, with painted patches of black carbon that measure the change in the electrical charge of the skin. A patent for the sensing method was filed in March 2010.

"Many of the types of infrastructures graded by the ASCE are made of concrete and could benefit from a new monitoring system like the sensing skin, including bridges which received a C grade, and dams and schools, which earned Ds," said Connor. "The safety of civil infrastructures would be greatly improved by having more detailed real-time information on structural health."

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